CYTOGENETICS AND BREEDING OF
Capsicum annuum L.

Dissertation Submitted for the Degree of

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IN

BOTANY

BY

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C E R T I F I C A T E

This is to certify that the dissertation entitled, "Cytogenetics and Breeding of Capsicum annuum L." , submitted to complement the requirements for the award of the degree of Master of the Philosophy in Botany, by Miss. Neeraj Sharma, is based on original research carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

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A C K N O W L E D G E M E N T

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CHAPTER- 1

INTRODUCTION

*Peter Martyn (1493) stated that Columbus brought home Pepper, Capsicum sp., from America and the red pepper, earlier used by red Indians only, reached every nook and corner of the world by 1600 A.D.

Genus Capsicum belongs to the tribe 'Solaneae' and sub-family "Solanoideae" of the family Solanaceae. It is a small genus of herbs, some species of which may sometimes becomes shruby. It is a native of tropical America. Many varieties of pepper are available in India and the plants of these varieties vary in height, size, shape, colour and pungency of fruit. These plants include bell-peppers, sweet peppers, chilis, , paprikas and pimentoes etc. Sweet pepper, among these, is least pungent and therefore it is usually used as a vegetable rather than a spice.

Chilis are also medicinally important and are used as counter-irritants in lumbago, neuralgia and rheumatic disorders. It also shows carminative action in dispepsia (Martindale, 1941), but if high doses are taken then chilis may cause gastroentritis. Recently, Monsereenusorn (1980) had reported a dose dependent decrease in the fasting blood

* See Thompson 1949.

glucose level after using Capsicum extracts. These also reduced intra-cardiac glucose-tolerance-curve at 30 and 45 minutes by 19.6% and 87% respectively.

Chilis are cultivated throughout tropics and subtropics. These are generally used as condiment for making pickles. Chili is extensively used in India as a spice. Curry powder is made by grinding dry chilis together with other condiments such as coriander, cumin and turmeric. Vitamin C is also extracted from fresh chilis. Chilis also contain a very pungent alkaloid "capsaicine", having a chemical formula $C_{18}H_{27}O_3N$. Fruits of chili are red due to the presence of capxanthein, capsorubin, zeaxanthein, lutein, crystoxanthein, carotenes and a few xanthophyll molecules. Chili seeds contain alpha-tocopherol (Vit E) in a concentration of about 2-4 mg per 100 gm and oil 9-13% in powdered dry fruits. According to Sastri (1950) the chemicals present in 100gms of green and dry chilis are as follows:-

Constitution	Green chili	Dry chilli
Moisture	82.60 gms	10.00 gm
Protein	2.90 gms	15.90 gm
Fat	0.60 gm	6.20 gm
Carbohydrate	3.00 gms	31.60 gm
Fibre	6.80 gms	0.10 gm
Mineral matter	1.00 gms	0.10 gm
Calcium	0.03 gms	0.16 gm
Iron	0.0012 gms	0.027 gm
Phosphorus	0.08 gm	0.37 gm
Vit C	111 mg.	50 mg
Carotene (Evaluated as Vit.A)	454 IU	576 IU

Besides the above mentioned constituents, occurrence of some traces of Alluminium, Barium, Copper, Iron, Lithium, Manganese, Silicon and Titanium have also been reported in chilis (Chr. Engel and de Vrie's (1946)and Lo'pezde Azcona et al.. (1945). Cobalt has also been reported from chilis (Andryushchenko and Vyrodova, 1981) but its quantity varies from cultivar to cultivar.

Chili is one of the most important commercial crops of India.Genetic experiments in chilis have been mainly limited to evaluations and selections of locally available varieties and their hybridizations because of absence of large variations. The absence of a varied genetic stock has limited the scope of this work because selections can be effective and usefull only. when sufficient variability is present in the material. But in the absence of sufficient variability in the nature mutagenesis, colchiploidy and hybridizations can induce the required vari - ability.

Climatic and soil requirements of chilis are like those of tomato. It is a warm season crop and intolerant of frost. But fruit development is adversely effected by a temperature of 100 °F and above, (38°C or more) for the production of fruits and seeds. Growing season lasts for 5-6 months.

Mutagenesis is most important method for inducing alterations in the genotype to enlarge the variability of

qualitative and quantitative characters in a shortest possible time and provides good scope for selections because the variability has been narrowing in chilis due to unidirectional selections and limited type of germplasm. Auerbach's and Robson's works (in 1946, 1947) with mutagens have opened new fields of research.

Physical mutagens like X-rays, UV-rays, gamma rays and chemical mutagens like Ethyl Methane Sulphonate (EMS) Diethyl — . Sulphate (DES),Nitroso Methyl Urea (NMU) Dimethyl Sulphonate (DMS),Nitroso Ethyl Urea (NEU), 5-Bromo-Uracil etc. are being used for inducing mutagenesis.

Hybridization and polyploidy has also come up as a handy tool for tampering with the genotype of the organisms and for inducing the large variations. Induction of polyploidy is also being used for inducing large variations in the gene pool (Behra and Patnaik; 1975). But hybridization is time consuming process, though an important tool for improving cultivated varieties by producing hybrids. Therefore in the case of limited germplasm it gives us a good scope for selection.

Hybridization and polyploidy both provide us important handy tool with the help of which we can transfer desirable genes from one plant to another. Colchiploidy and mutagenesis are processes through which genetic variability

of quantitative as well as qualitative characteristics can be obtained rapidly. All these methods are very important for the induction of variations in the plant materials.

The present study involves the mutation breeding, induction of colchiploidy and interspecific and intervarietal hybridizations for the production of varieties which are high yielding as well as contain large amount of capsaicine, Vit E, Vit C, etc. There have been some attempts of breeding for developing disease resistant varieties, resistant to different viral and becterial diseases, so that huge loss of crop can be prevented or atleast reduced partially.

Following programme of investigation has been chalked out for improvement of the yield characteristics of chilis :-

(i) Five cultivated varieties will be studied for 41 quantitative and qualitative characteristics (after Pickersgill et al., 1979).

(ii) Intervarietal and interspecific hybrizations will be made and the hybrids will be studied cytologically as well as for detecting heterotic improvements of traits which will be determined by comparing hybrids with their parents.

(iii) A comparison of F_1,F_2 and F_3 populations will be made with respect to the occurrence of variability and improved qualities.

(iv) Mutants will be isolated, selfed to produce M_2 and M_3 generations and cytology and cytology and morphology of the plants of M_1, M_2 and M_3 generations will be studied.

(v) Later, all the mutants and hybrids will be tested for resistance to viral, bacterial and fungal diseases.

Resistant and improved hybrids and mutants usefull for breeders, cultivators and consumers will be selected for release after the required tests.

TAXONOMY FLORAL BIOLOGY AND CULTIVATION OF CHILI *Capsicum annuum* L.

2.1 Taxonomy :

Genus *Capsicum* belongs to the tribe 'Solaneae' belonging to the subfamily 'Solanoideae' of the family '*Solanaceae*'. It is a small genus of herbs, some species of which may some times become shruby. It is a native of tropical America. Many varieties of pepper are available in India, and plants of these varieties vary in lengths, size, shape, colour, and pungency of fruits. These plants include bell pepper, sweet pepper, chilis paparika and pimentos etc. Sweet pepper among them is least pungent and therefore it is usually used as vegetable rather than a spice .

The present taxonomic status of pepper *Capsicum annuum* L. may be stated as follows :-

Kingdom	-	Plantae
Division	-	Spermatophyta
Sub-division	-	Angiospermae
Class	-	Dicotyledonae
Family	-	Solanaceae
Tribe	-	Solaneae
Genus	-	*Capsicum*
Species	-	*C. annuum*

Botanical description :

Habit - Annual, herb,

Root - Tap root system

Stem - Erect, branched, solid, cylindrical, green

Leaves - Simple, entire, opposite, acute,

Inflorescence - Cymose usually a typical axillary cyme.

Flowers - Usually pedicillate, hermarphodite, actinomorphic, regular, hypogynous, complete, bracts, and bracteoles are absent.

Calyx - 5 sepals gamosepalous, lobes small, persistent and often enlarge in fruits, oblong, acute, green.

Corolla - 5 petals, gamopetalous, rotate, lobes oblong acute white twisted or valvate aestivation.

Androecium - 5 stamens, alternate to petals, polyandrous, epipetalous, filaments short anther oblong bicelled.

Gynaeceum - 2 carpels (bicarpillary), Syncarpous ovary obliquely placed in the flowers, superior, globose, bilocular; axile placentation; Style simple hairy at the base.

Ovary - Superior, typically bilocular, but in apical portion it becomes unilocular.

Fruit - Berry, with persistent calyx.

Seed - either smooth or pitted.

Germination - epigeal germination.

2.2 Floral Biology :

The study of floral biology has now becomes essential for an intelligent breeding programme. Flowers of the genus Capsicum are typically pentamerous, hermaphodite with pedicel 10-20 mm long. Calyx is companulate shortly 5-7 dentate, ribbed, 2 mm long and enclosing base of flower. Corolla is rotate companulate, gamopetalous, 5-7 partite 10-20 mm in diameter. Most frequent abnormalities of Capsicum flowers are petaloidy and pistilloidy of calyx lobes, non abcission of corolla formation of staminoides,

proliferation of stamens, absence of filaments, protrusion of styles, above lightly closed petals, non-abcission of the styles, which remains attached to the ovary and increases in size as the fruit grows and ripens with the fruit itself, taking on the colour typical of fruit.

2.2.1 Anthesis :

The opening of flowers is adversely effected on dull and wet days but in long spells of bad weather flowers do open Anthesis is completed in the morning by 8-9 A.M. and most flowers. Shed their pollen at 9.00 A.M. The rythm of flowering and total number of flowers produced per plant may vary enormously according to the genotype.

2.2.2 Pistil and Receptivity of Stigma :

Pistil has an ovary with longitudinal diameter of 2.5 mm and a transversal diameter of 1.5-5.0 mm, containing 2-4 carpels, style has 3.5 to 6.5 mm long, a capitate, lobed or papillate stigma with a mean diameter slightly greater than that of style is present.

Receptivity of Stigma varies with temperature during anthesis. It is highest on the day of anthesis, when the anthers are fully developed but are still indehisced and corolla is still closed but is above to open and it lasts for a maximum of 4-7 days and 5-9 days after emasculation at white bud stage.

2.2.3 Anthers microsporogenesis and pollen grain :

There are 5-7 stamens per flower. They have filament 1.8-3.5 mm long with anthers 1.2-2.0 mm wide and

2-4 mm long. Dehiscence is lateral along a line running the whole length of the anther. A normally fertile flower may contain 1.0-1.5 mgm of pollen grains.

2.3 Cultivation :

2.3.1. Soil and its preparation :

Chili is a crop which is grown all over the India. It is cultivated on a loamy soil having 0.2 ppm solution of phosphate and watered at 0.33 bar. It should be irrigated lightly before sowing to maintain proper moisture content in subsurface of soil during seed-germination. In the saline soil the yield is reduced very rapidly with the increase in the concentration of Na^+ and Cl^- ions. Before the commencement of the rainy season, the field is thoroughly ploughed to ensure maximum soil aeration and it also helps to eliminate the weeds.

2.3.2 Manuring :

The best Nitrogen fertilizer dose for high pepper yield is 224 kg/ hac. The application of farm yard manure increases the chlorophyll content of leaf and results in to early germination and growth of seedlings. Farm yard manure 200 kg/hac with phosphate granules 2kg/hac increase the yield of pepper (Shinde and Yaadava 1982). The highest uptake of macronutrient by chili plant takes

place between 50-70 days after transplantation (Miller, Mccollum and Claimon (1979). Addition of K and NPK to the soil increases the yield of chili, with high level of N and P doses the productivity of pepper plant was high with higher protein, ascorbic acid, and capsaicine content. Maximum yield of bell pepper can be obtained with the application of 200 lbN/acre. Ammonium sulphate is the best source of N for chili plant and increases vit E, B, and C, greatly while Vit E increases on the application of any nitrogen source.

2.3.3 Foliar fertilization :

Pepper plant gives very high yield with a root fertilization of 19.6 gm/L and foliar spray of Urea increases the yield and ascorbic acid content of sweet pepper (Nowak 1980 a).

2.3.4 Sowing :

Timely sowing of chili crop is important for getting good and healthy seeds. The choice of a sowing pattern depends on many features of crop. The seeds are sown in thoroughly ploughed field to ensure maximum soil aeration, soil should be irrigated lightly. Spacing of the crop plants should be done properly.

2.3.5 Irrigation :

Kays, Johnson, and Jaworkshsi (1976) have recommended multiple cropping of pepper together with

trickle irrigation, mulching and soil fumigation for very high yield. Effect of flooding and poor drainage on the growth of Capsicum annuum var. "longum" was reported to be poor growth, yellowing of leaves, blackening of the root tips, development of brown to black deposits on the roots tips, distinct swelling at the junction of root and shoot, development of greater amount of cortical air spaces in the roots, increases in their diameters and very low survival and harvest in flooded soils. Plants grown in well drained soils showed best growth. They started flowering when ten weeks old. They could survive short-term flooding but were sensitive to prolonged flooding.

2.3.6 Temperature Effect :

Nilwik (1981) found that the day temperature of 25°C increases the total leaf area and dry weight in pepper. Rylski and Spigelman (1982) reported that a night temperature of 15°C with a day temperature of 24° to 28°C was the best for fruit setting and production of higher number of fruits per plant.

2.3.7 Storage :

Coleman et al (1979) reported that solar dried and hot air-dried green peppers showed rapid reduction in

Vitamin "C" content at 21°C to 30°C. Tonelli *et al* (1981); reported that storage of green sweet pepper at 85-90 % relative humidity and 10°C temperature resulted in to least deterioration in the quality of the pepper fruit and most favourable storage temperature was found to be 20°C.

CHAPTER- 3

REVIEW OF LITERATURE

3.1 Origin and taxonomic relationship :-

3.1.1 General:

Red peppers are popular today in Central America and Andean highlands. Many species are also found in South Asia. According to many taxonomists New World is the main Centre of its origin. Dried chili-pods have been discovered from the tombs in Peru and are believed to be more than 2,000 years old, as stated by Stafford (1926). Red peppers were popular as a food condiment among the red Indians. Chilis were not used as essential element of food or as condiment in old world,* Decondolle (1886) held that lack of food reference of this genus in ancient literature was a sufficient proof that chilis were not used in that period. The centers of the diversity of the cultivated peppers (Capsicum annuum) is Mexico and Guatemala and of C. frutescens (both varieties like cultivated and wild) is Central and South America. According to Vavilov's theory these areas are centers of the origin of Capsicums (Bukasov, 1930); Smith and Heiser, (1957 b). It is said that pepper was brought to the old world in 1493 by Columbus (Boswell, 1949); Portugese introduced

*See Thompson 1949.

Capsicum to India from Brazil. It was reported from China during the last quarter of the 17th Century (Sturtevant,1885).

3.1.2 Species and Varieties and their Recognition:

* Linnaeus (1753) in the first Edition of Species.Plantarum "reported that there were only two species of Capsicum and three more species were added later *(1797). After some years later 100 species and varieties of chili were recognised by Fingerhuth (1832)*Irish (1898) recognised only two species viz. Capsicum annuum and Capsicum frutescens and he listed all botanical varieties under Capsicum annuum but after some times, (during 1924) Bailey recognised only one species with 5 botanical varieties. Smith and Heiser (1951) included all types of varieties under Capsicum annuum. They listed pungent variety 'Tobasco ' and some other varieties under Capsicum frutescens. Bailey (1924) has divided Capsicum frutescens in to following 5 groups.

1. Group "Cerasiforme"; Cherry pepper (pungent).
2. Group "Conoides": Con-pepper with pungent and conical or oblong cylindrical fruits.
3. Group 'Fasciculatum': Red-clustre having erect fascicled fruits, about 3" long and 1/4" thick, red and extremely pungent.

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*See Thompson 1949.

4. Group 'Longum'; Long pepper having drooping elongated pungent fruits, ranging from 3-12" long and tapering at apex including commercial varieties like long-red, long yellow and chili cayenne.
5. Group 'Grossum'; Bell or sweet-pepper having a large puffy depression at the base of fruit and furrowed sides, red or yellow coloured and has mild flavour.

3.1.3 Origin of species and varieties and their interrelationships :

Pickersgill (1971) holds that C. annuum, C. baccatum and C. chinense has been domesticated independently from wild forms. That is why, each of these has a respective wild ancestor, e.g., C. chinense has wild plants which can be its ancestors. C. frutescens also has a wild form which has been maintained as distinct species while wild and cultivated forms within C. annuum and C. baccatum are distinguished at varietal level only.

Distinction between wild peppers with small, erect and deciduous red fruits and domesticated peppers with large pendent non deciduous fruits of various colours is far from clear cut various intermediate, types occur which have small erect non-deciduous fruits or large pendent deciduous fruits. These Intermediates are very frequent in C. annuum and and C. chinense . These are not occasional chance hybrids but well.established types .. Some wild forms of Capsicum annuum can not be distinguished from

C. frutescens and some domesticated peppers can not be included either in domesticated C. annuum or domesticated C. frutescens . Some forms have corollas quite dissimilar to those of C. annuum, C. chinense , or C. frutescens (Pickersgill , Heiser, and Mc Neill 1979). Barbara,Pickersgill; C.B. Heiser and J. Mc. Neill (1976)(See "The Biology and Taxonomy of the Solanaceae 1979) have divided cultivated Capsicums in to 5 species and four groups viz.

(a) domesticated C. pubescens Ruit. Z and Pav.,

(b) domesticated C. baccatum L.,

(c) domesticated C. annuum L., and

(d) domesticated Complex of C. chinense Jacq-C. frutescens L.

According to them the cultivated and domesticated form of C. baccatum has been derived from the wild forms of the same species. Generally the species of capsicum have same chromosome number i.e 2n=24 and their basic caryotype consists of one pair of acrocentric chromosome and eleven pairs of meta and submetacentric chromosomes. This basic caryotype is found in C. chinense, C. frutescens, frutescens like wild Capsicum annuum, Costa, Rican wild C. annuum and several other wild forms of C. annuum. But domesticated C. annuum has a distinctive caryotype with 2 pairs of acrocentric chromosomes. It is found in wild C. annuum of Central Mexico. The second pair

of acrocentric chromosome seems to have arisen as a result of an unequal reciprocal translocation, between two of the pairs of meta or Submetacentrics in the basic components (Koompai; 1976 ; Pickersgill,unpublished). Translocation heterozygotes produced by appropriate crosses between wild and domesticated or within wild forms of C. annuum have their 30-50 % reduced pollen stainability. Thus there are sterility barriers with in C. annuum as marked those between C. chinense and C. fsutescens or between wild C. annuum (See Pickersgill, Heiser and Mc Neill, 1979) It seems that immediate ancestor of the present day C. annuum, C. chinense, C. frutescens group was a variable complex of wild forms carrying the basic caryotype and perhaps was similar in appearance to frutescens like wild C. annuum found today. This probably occurred in Southern North America, Central America and West Indies. Perhaps it was self-compatible and occurred in small,distantly placed, populations and therefore did not permit inter-population gene exchange. This resulted in to development of typical wild C. annuum, wild C. chinense and wild C. frutescens. From this complex of partially differentiated wild forms, the domesticated peppers developed by independent domestication of local wild peppers in Mexico (C. annuum) South America (C. chinense) and Mesoamerica

(C. frutescens). According to J.Mc, Leod, Guttaman, Hardy and Eshbaugh (1982) studied evolution of chili peppers. According to them genus capsicum is a complex of 20-30 wild species, and 5 domesticated texa. They hold that genus with all its species, except one, viz, C. anamolum (Eshbaugh, 1980), is of New world origin, They stated that domesticated texa and associated wild species could be organised in to 3 groups, one purple-flowered group includes C. cardenasii, C. eximium and C.pubescens; one white flowered group includes C. baccatum var. baccatum, C. baccatum. var. pendulum and C. praetermissum ; the second white flowered group includes C. annuum variety aviculare, C. annuum var, annuum, C. chinense and C.frutescens L. However based upon breeding and electrophoretic data, C.chacoense with white flowers, does not fit in to any one of the recognised groups. According to Mc Leod et al., (1982) C. chacoense is distinguished genetically from all these groups yet it is closely related to the purple coloured flowered group of C. pubescens and it is equally distant from both white flowered groups. Egawa and Tanaka (1984) studied cytogenetic relationship among 3 species of chili peppers viz., C.chinense, C. frutescens and C. baccatum by studying their interspecific and intra-specific hybrids.

In a cross between C. baccatum X C. frutescens at MI of PMC, chromosome pairing was regular with 12 bivalents, and average viable pollen grains were present. The average chromosomal distribution of the hybrids showed I (0.87), II (10.22), III(0.31)IIII (0.34) and IIIIII(0.06). Similarly the hybrids between C. chinense X C. frutescens , also showed twelve bivalents and regular pairing of chromosomes with the average of 0.06 I and 11.97 II. They appear not to be distinct species but a single species with 2 varieties. It also shows that these 3 species had common ancestors but C. baccatum had derived early from the ancestral stock.

3.1.4 Characteristics of wild and Cultivated Species :Following are some of the pure wild species e.g. C. cardenasii, C. cornutum , C. eximium C. galapogense, C. chacoense, C. geminifolium, C. minutiflorum C. praetermissum. C. schottianum and C. scolnikianum as identified by (Hunziker, 1950, 1954, 1961.b, Heiser and Smith,1958, , Eshbaugh, 1964). These occure throughout the central and south America. But other workers like Lippert, Smith, and Bergh (1966) distinguished 12 wild and cultivated species e.g.(a) C.chinense, (b) C.frutescens,(c) C.galapogense, or (d)C. annuum, (e) C. schottianum (g) C. microcarpum,or C. pendulum, (h)C.eximium, (i) C.praetermissum, C.scolnikianum. They described following morphological characters distinguished these twelve species (Table I).

T A B L E - Ist

Species floral character	C. pendulum or C. microcarpum	C.praetermissum	C.eximium	C.pubescens	C.cardenasii	C.scolnikianum
Corolla colour	White	White to lavender	White to lavender	purple	blue	Yellow
Corolla throat spots	green to yellow spot	Yellow spot	Yellow spot	none	greenish yellowspot	X
Corolla shape	rotate	rotate	rotate	rotate	companulate	companulate
Anther colour	yellow	yellow	yellow	purple	pole-blue	X
Calyx teeth	present	present	present	present	present	present
Number of flowers per node	1-2	1	2-3	1	1-2	X
Corolla colour	White	X	white to greenish	white	white	white
Corolla throat spots	none	none	none	none	none	none

Species floral character	*C. pendulum* or *C. microcarpum*	*C. praetermissum*	*C. eximium*	*C. pubescens*	*C. cardenasii*	*C. scolnikianum*
Corolla shape	rotate	rotate	rotate	rotate	rotate	rotate
Anther colour	blue to purple	blue	blue	yellow	yellow	yellow
Calyx teeth	present	none	present	none	present	none
Number of flowers per node	1	2-3	1	1	3-5	5-7

3.2.1 Cytology :

No. of Chromosomes:

Chromosome number of Capsicum sp. as reported by Huskins and La-Cour (1930), was n = 12. The same has been confirmed by several workers. (Dixit (1931); Yamamoto and Sakai (1932) ; Tokunaga (1934); Raghavan and Venkatasubhan (1940); Pal et al (1941); Chennaveeraiah (1947); Schnack and covas (1947) ; Sinha (1950); Vazart (1950a, 1951) Ohta (1962a, 1962c); Eshbaugh (1964). Kaustoff (1926) reported n = 6, by mistake (Dixit (1931) Raghauvanshi and Joshi (1964) confirmed n = 12 in C. frutescens while Indira and Abraham (1977) and Khan and Siddiqui (1981) confirmed the same for C. annuum.

3.2.2 Chromosomal dimensions, caryotypes and abnormalities :

Chromosomal sizes have been reported to be small by Christensen and Bamford (1943) and Marks (1952) but large by Sinha (1950). The chromosomal sizes at meiotic metaphase, were found to be nearly 4.1 μm long 0.5 μm in diameter and having a volume of 184 μm^3 (Vazart 1950a). At the end of prophase the shapes of chromosomes were found to be rod-shaped, U-shaped, V-shaped, or J-shaped, with prominent primary constrictions (Sinha, 1950; Vazart, 1950a). Two SAT-chromosomes have been discovered by Dixit (1931) and Vazart (1950a) in the somatic cells of C. annuum while Sinha (1950) and Ohta (1962a, 1962c) found only one SAT-chromosome.

Karyotopyes of C. annuum and other species have been reported by many workers (Vazart, 1950b;Ohta 1962 b,c; Carluccio and Saccardo, 1978; Chennaveeraiah, 1947; Sinha, 1950). Ohta (1962a, 1962c) divided six species of Capsicum into four karyotypic groups. This classification was based upon the presence or absence or number of satellites and secondary constructions. Smith and Heiser (1957a) and Hirose et al., (1960) studied the cross-compatibility reactions by making interspecific crosses and found that species groupings of the karyotypes correspond closely to cross-compatibility reactions. Meiosis has been reported to be normal with 12 bivalents in C. annuum (Huskins and La-Cour, 1930 ; Dixit, 1931; Pal et al., 1941; Vazart, 1951). Vazart (1950b, 1951) reported that the diameter of the nuclei was to 10μm and volume 580 μm^3 and it was slightly larger than that of meristematic nuclei which had a diameter of 9μm and volume of 380 μm^3 in C. annuum. Meiosis is normal in the pollen mother cell of C. frutescens. Chiasmata formation is limited to achromatic regions and maximum of 3 chiasmata per bivalent has been reported (Abde-el and Maksood Mohmed, 1953). Zatyko and Moor (1973) also described different varieties of red pepper. Swaminathan et al. , (1959) observed that nearly all bivalents are of ring-type with chiasmata in both arms. They also reported irregularities during microsporogenesis.

3.2.3 Induction of Meiotic abnormalities :

Kalovkyan (1968) has reported the frequent occurrence of fragmentation and bridge formation in C. annuum after the

treatment with nitroso-ethyl -urea (NEU) and nitrosomethyl urea (NMU). Illieva and Molkhova (1975) reported the effect of gamma irradiation on the microsporogenesis of C. annuum after the application of doses of 0.3 0.5 1.0 and 1.5 Kr during the period of differentiation of pollen mother cells. The process of meiosis was stopped at different stages as a result of exposure of the material to different doses of irradiation. If the spindle was broken at Metaphase I, the chromosomes showed structural changes connected to the formation of fragments, bridges etc. even at the lowest irradiation doses. Lakshmi and Baparao (1977a) have reported 95 % cytomixis in the chili hybrids. At diakinesis 3 to 101 chromosomes were visible with multivalents of up to six chromosomes. Subhash and Nizam (1977)reported that th increasing dose of X-ray irradiation resulted in to the formation of increased number of multivalents, fragments, bridges, micronuclei. It also resulted in to multiple spindle formation in C. annuum.

Nagalla, Lakshmi, Baparao and Nagalla (1977) have reported partial desynapsis of mutants obtained from X-ray and EMS treated M_1 population of C. annuum . It showed variable number of univalents (2-24) at diakinesis and metaphase-I. X-ray irradiation produced more anamolous cells than treatment with EMS.

Katiyar (1977) described desynaptic behaviour in a variant, isolated from a variety of C. annuum with erectly

oriented fruits, following 20 Kr gamma irradiations. It showed meiotic irregularities like micronuclei, miniature polyspory and gametes with genetic imbalance.

Katiyar (1978) has reported that the irradiation of dryseeds of C. annuum with gamma rays at 5,10,15 and 20 Kr level showed abnormal chromosomes with stickiness, clumping, altered association, breakage, bridges, unequal segregations laggards and abnormal microspores. They also stated that with the increasing dose of gamma rays pollen sterility increased and abnormalies present were much more in M_1 generation than in M_2.

Lakshmi and Rao (1978) described chromosomal interchange in a yellow fruited variety of pepper. A translocation heterozygote of C. annuum L. (2n = 24) with an association of four non-nuclear chromosomes showed vigorous growth but irregular meiosis and pollen sterility of 83.5%. Cawood (1980) reported in Capsicum the aggregation of chromosomes into a synizetic knot during zygotene and the delayed constriction of chromosomes during a diffuse stage after pachytene.

Meshram, Narkhede and Deshmukh (1981) reported spontaneous multiple translocations in Capsicum annuum. It was a healthy plant with broad green leves and large flowers. At metaphase, Ist rings of 4 and 8 chromosomes and chains of

4,6,8,10,12 and 18 chromosomes were observed. Non-disjunction, laggards, chromatin bridges and irregular distribution of chromosomes were observed at abaphase I and this resulted into 90-100% sterility in pollen.

Dimitrov (1981) has reported that caffeine decreases the gaps caused in the chromosomes by alkylating reagents like N-nitroso N-methyl urethene or by gamma rays.

Abida, Kuriachan and Kuriachan (1983) have described spontaneous interchange heterozygote in C. chinense with 44.4% pollen sterility. They also showed 10II + I ring or chain of 4 chromosomes or 10II +1III +1I or 11II + 2I in addition to cells with 12II. Out of the 12 pairs of homologues, there was one homomorphic and a second heteromorphic pair of satellited chromosomes. Perhaps the smaller of the heteromorphic pair of chromosomes was the normal and during the interchange a small satellited part of its homologue shifted to another non-satellited centric pair of non-homologous chromosome from where a larger segment came back to its homologue producing the larger member of the heteromorphic pair.

Wagner (1983) has described Vascular apparatus responsible for druse crystal formation in Capsicum annuum. Sadanandam and Subhash (1983) reported desynapsis in a mutant

C.annuum which was produced by treatment with DES and showed 72 percent pollen sterility. This characteristic was controlled by a single recessive gene.

Sadanandam and Subhash (1985) reported that aneuploidy was induced following 40 Kr irradiation in Capsicum with highly irregular meiosis, variable chromosomal association at diakinesis, lagging chromosome at anaphase I and appearance of micronuclei at telophase II. Kumar, Aniel and Rao (1985) reported great meiotic abnormalities from the desynaptic plants of C. frutescens, isolated from natural population ; this plant showed reduced pollen fertility.

Kumar, Aniel, Pande and Raja Rao (1986a) noted the mode of bivalent formation in a desynaptic mutant of chili and found that frequencies of pollen mother cells with different numbers of bivalent significantly deviated from those expected with a normal distribution. This desynapsis in the mutant was controlled by a recessive gene.

3.2.4 Chromatin Extrusion :

Lakshmi and Bapa Rao, (1986), studied the effect of temperature, fixative, division stages, and genotypes on the manifestation of the phenomenon of chromatin extrusion in chili.

3.2.5 Changes in ribosomal content of fruit :

Gounaris et al (1986) reported disappearance of ribosomes during conversion of chloroplast to chromoplast. It was noted in the development of chili fruit from green to red fruited condition.

Kumar, Aniel, Panda and Rao (1987a) reported that autotetraploids of C. annuum showed considerable decrease in chiasmata frequency together with laggards at anaphase I or II. Seed and pollen fertility was very low.

Kumar, Aniel Panda and Raja Rao (1987) studied hibrids between C. annuum variety G_3 X and C. frutescens veriety "tobasco" (H_1) and another cross between C. frutescens and C. annuum var "ceraciformis" (H_2). They found that parental species differ from each other by 2 translocations one inversion and some minors structural alterations. Meiotic irregularities and pollen and seed sterilities were higher in the hybrids obtained in the first cross (H_1), probably due to differences in respect of their crossable relationship chromosome pairing and fertilities.

Pande, Aniel, Rao (1987b) reported desynapsis was introduced in a chili variety 'ceraciformis' of C. annuum after treating it with colchicine showing regular pachytene pairing but at Metaphase I it showed high frequency of univalents which resulted in to high frequency of sterility.

Meshram and Patil(1987) reported meiotic anomalies and chromosomal stickiness in chili C. annuum during microsporogenesis due to the effect of EMS, DMS and acrid juice of mango. In DMS 0.2% concentration, percentage of PMCs with univalents-multivalents association was high. More chromatin bridges laggards, spindle abnormalities and micronuclei were produced with higher concentrations and longer duration of treatments.

3.3. Genetics :

Genetics of different species and cultivated varieties of Capsicum has been studied by many workers with regard to variability, heritability, selection, genetic advance, correlation of some characteristics and breeding behaviour.

3.3.1 General :

Smith and Heiser (1957a) studied breeding behaviour of some cultivated peppers; Morgan, Jr.(1960) studied the genetic control of polyploidy in C. frutescens. Ramanujam and Tirumalchar (1967) found considerable phenotypic and genotypic variability in red pepper. Betlach and Vytopil,(1970) and Silvetti and Giovannelli, 1976), studied quantitative characters like plant height, leaf number, number of fruit per plant, fruit size, average fruit yield per plant and many other characters of sweet pepper varieties which showed variabilities due to dominance of some and overdominance of other characters.

Jo et al., (1973) made correlation studies and Dikki and Anekeenko (1973) studied the problem of restoring fertility in stamen-less forms of pepper and found that new fertile forms, thus obtained differed from normal fertile varieties in the completeness of anthers. Rao, Jaisvani and Patel (1974) found phenotypic and genotypic associations among days to flower, days to pod maturity, fruit setting ability in summer, numbers of pods per plant and yield of green and dry pods per plant in chili. Fruit setting ability in summer showed high correlation with green pod yield and influenced total fruit yield through days to flower and days to pod maturity. Zubrazycki, Pahlen and Vonder (1974) found that six genes were linked in pepper these are-

(1) m (marbled leaves)
(2) anv (eliptical cotyledons and long narrow leaves)
(3) div-3 (seedlings with diverse characteristics)
(4) aur (golden cotyledons and leaves)
(5) dvg (deformed undulate leaves, green with yellow spots) and
(6) brl (controlling stem elongation, leaf shape, size and colour).

Arya and Saini (1976) observed high value of genetic advance for fruit yield in Capsicum with fruit-size contributing

towards fruit yield maximally while close association was found between fruit-size and stem thickness and plant height and fruit number respectively. They also noted that plant height, leaf length, fruit weight, and fruit number were negatively correlated with yield. High heritability estimates were found in bell-peppers for fruit-number per plant and fruit yield.

Lee (1976) found that characters like high yield, diameter of stem, number of fruits per plant and fruit weight responding to selections in chili. Awasthi, Joshi and Ghildiyal (1976) estimated for chilis, high genetic advance for plant height, fruit-length and fruit yield. High heritability but lower genetic advance indicated non-additive gene effect for number of branches per plant, fruit diameter and average fruit-weight but fruit number per plant showed average heritability. Rocchetta et al (1976), during the study of relationships among yield, weight, number of fruits per plant and other phenotypic characters, showed that yield depended fundamentally upon weight and number of fruits per plant.

Combining ability and reciprocal differences, studied through dialleic crosses, showed reciprocal effects for some

characters like days to flowers, number of fruits per plant and days to maturity. Singh and Singh (1977 a.c) concluded that plant height, days to maturity , number of fruits per plant, yield per plant and number of branches per plant, all appear to be under the polygenic control and are influenced partly by the environment.

They found genetic advance high for number of fruits per plant and yield per plant but environmental component of total variability was very low for fruit length, fruit thickness and days to flowering.

Singh and Singh (1976,b,c,e,1978a) found additive dominance and environmental variance present in varying proportions for number of branches, days to flower, days to maturity, fruit length, fruit thickness, and fruit number. Yield showed positive heterosis while plant hight showed negative heterosis. All these characters showed high general and specific combining ability. They also studied F_1 and F_2 generations of inter-varietal hybrids of chili and found seven yield components giving yield 10% higher than that predicted on the basis of selection. Some of these components were days to flowering, fruit length, and number of fruits per plant.

Chang (1977) studied 12 varieties of chili and found great significant variation in them for plant height,

number of branches per plant, fruit length, fruit thickness, days to first flower, days to maturity of fruits, total number of flowers and yield. High heritability estimates were observed for height, days to flower, days to first maturation of fruit and stalk length. Yield was found to be positively correlated with fruit weight, total number of flowers, fruit number and stalk length.

Al-Hamidi, Gengaihi and Shalaby (1977) also made variability and heritability studies in C. frutescene while Arya and Saini (1977) made variability studies on salad-type pepper and found genetic advance for fruit yield per plant fruit size and fruit number per plant.

Gill, Asawa, Thakur and Thakur (1977) made correlation studies in C. annuum var. "grossum" and found that selection for high yield should mainly be based upon the number of fruits per plant.

Mehra and Peter (1980b) showed genetic advance in chili through selections for yield, primary branches per plant, fruit number per plant, fresh weight of pods and seeds and dry weight of pods. He showed that straight selection was superior to the selection through discriminant functions based upon fruit length, fruit girth, locules per fruit and seed weight per pod.

Sundaram, Ramakrishnan, Renganathan and Ramalingam (1980) found great genetic and geographic diversity in 50 varieties of C. frutescens , mostly contributed by number of branches and number of fruits per plant. Ramakumar, Ramachandran Murthy and Durga Prasad (1981) found high heritability values and genetic advance for plant height, number of fruits per plant, girth of fruits and yield which were found to be highly correlated with number of fruits, plant height, and plant spread. The value was positive for girth of fruit, number of fruit per plant and plant spread while it was negative for plant height and number of buds per plant.

Ramana Rao, Jaisvani and Asawa (1981) reported that flowering maturity, fruiting ability in summer and pods per plant were most important traits of C. frutescens, accounted for 55.34% of variability and that selections lead to the better fruiting, early flowering and maturity. Rao and Aniel (1983) have also observed that desynapsis in Capsicum is controlled by a single gene. Meshram and Narkhede, (1985) found one desynaptic mutant with normal pairing upto diplotene stage but no pairing at diakinesis and metaphase Ist. stages.

Mccammon and Homma (1984) found that two recessive genes "ct" and "dt" control umbrella type inflorescence and "fa" determined fruit bearing habit but in the presence of

a dominant supressor gene they produced indeterminate types of inflorescences. Variability analysis in chili by Gupta and Yadav (1985) showed high genotypic and phenotypic coefficient of variation for fruit girth, number of branches, fruit weight, and number of fruits per plant. Egawa et al (1985), reported structural differentiation of chromosomes by reciprocal translocations in Capsicum annuum. Meshram et al. reported about a desynaptic mutant in chili (Capsicum annuum). Chromosomes were normal up to diplotene substage of Prophase I of meiosis. But no pairing was observed at diakinesis and metaphase I and 234 univalents were observed in most of the PMCs studied. Inheritance studies indicated that desynapsis was conditioned by a monogenic recessive factor.

Grafting also induces changes in Capsicum. Yagishita and Hirata (1986) found that grafting in Capsicum induced changes in fruit shape. But these changes were found to be temporary. Shifriss (1987) found 3 genes in Capsicum annuum viz male sterility(ms) erect fruit position (up) and anthocyanin-less (al) which were independently segregating characters. Inverted apex characteristic is also independent of male sterility (ms). Similarly the gene for premature fruit pigmentation also segregates independently of 'up' gene and close linkage is present between round leaf (rl) and "al", partial linkage was suggested between "ms" pointed apex "pt"

and gane controlling premature green colour but independent segregation was noted with the gene controlling green colour.

The inheritance of following characters has been studied in detail :

3.3.2 Length, width, shape and weight of fruits :

Fruit length is multigenic character, rather than based upon a single gene action. Deshpande (1933) and Miyazawa (1953) stated that nine genes control fruit length.

Khambananda (1948) and Miyazawa (1953) discribed that fruit size and weight appeared to be quantitatively inherited in Capsicum and their action was supposed to be multiplicative, dominant and epistatic for large fruit-size. Khambananda later (1948, 1950) denied genic control of fruit length and width and suggested that these characters are largely expressions of shape and weight factors. The gene "O" for oblate fruit shape has proved to be completely dominant to the gene"O" for the elongate fruit according to Paterson (1959). But incomplete dominance for oblate gene was suggested by Khambananda (1950). Paterson (1959) had also suggested that certain additional genes controlled fruit length . Khalfallah and Abdel-al (1975) reported high degree of nonadditive gene action for fruit weight and additive gene action

for fruit size and weight for some other varieties. (Milkova, 1979; Thakur, Gill and Bhagchandani, 1980; Singh and Singh, (1982). Daskalov and Milkova (1978) also reported that role of the non-additive genes was greater for fruit weight.

High combining ability was reported in California Wonder (bell-pepper) (Betlach, 1973; Moravec, 1973) and heterosis, in intervarietal crosses, for fruit length was reported by Singh and Singh (1978b).

Awasthi, Joshi and Ghildiyal (1976) found non-additive gene action for fruit diameter and average fruit weight. Rochetta, Giorgi and Giovannelli (1976) found heterosis in F_1 generation for yield, independent of parental type. Arya and Saini (1976) reported California Wonder to be very high yielding among many bell-peppers and that its fruit size contributed towards fruit yield maximally. But Singh and Singh (1978c) found non additive gene action to be predominant for fruit yield.

Increased fruit size is also obtained by the use of α naphthalene acetic acid treatment, according to HariHaran, Molly and Unnikrishnan (1984).

3.3.3. Number of fruits per plant :

Nandpuri Gupta and Thakur ,(1971) reported high heritability estimates. Betlach (1973) and Moravec (1973) reported high combining ability. Khalfallah and Abdel-al (1975) reported high degree of non-additive gene action. Awasthi, Joshi and Ghildiyayal (1976) observed intermediate effect between additive and non additive gene action. Rocchetta et al. (1976) found heterosis with F_1 generation for fruit number in capsicums. Heterosis for fruit number was reported by Singh and Singh (1978b) in inter varietal crosses. Overdominance was observed for fruit number per plant in C. annuum (Thakur, Gill and Bhagchandani, 1980). But Singh and Singh (1982), found additive component was lower than non-additive component.

3.3.4 Cluster / non cluster fruit habit :

Barrios and Mosokar (1972) reported that non -cluter habit in C.frutescens is monogenically controlled and dominant while cluster habit is controlled by a single recessive gene, but hybrids from a cross C. annuum X C. pendulum , produced fruits in clusters (Daskalov, Rusenova and Milkova, 1973). Pre bifurcation shooting, terminating into to a fruit in C. annuum, though a quantitative character

yet appears to be controlled by only a few genes. This bunchy habit of the fruit was found to be dominant in a Bulgarian cultivar of pepper.

Shifriss and Hakim (1977) and Sundaram et al.,(1980) recorded that chief contributors for genetic divergence in Capsicum frutescens are number of branches and number of fruits per plant while Mehra and Peter (1980b) found the fruit yield to be chief contributor for variability in C. annuum.

Thomas and Peter (1987) proved that clusture bearing fruit habit in Capsicum annuum was recessive and governed by two pairs of genes, out of which one pair was epistatic.

3.3.5 Thickness of fruit wall and flesh :

Dempsey (1960) reported that it is controlled by 8 pairs of genes with multiplicative effect. Role of non additive genes was greater for pericarp thickness (Daskalov and Milkova 1978).

Silvetti and Giovannelli (1980) found that in pepper cultivars, variation was due mainly to additive genetic components with very small dominance effect for mesocarp thickness.

3.3.6 Fruit colour (mature and immature):

Webber, 1911; Atkins and Sherrard, 1915; and Shaw and Khan, 1928, reported the gene Y in yellow colour is dominant over the recessive red colour gene y. It was confirmed by Smith (1950) and Khan and Munir (1954). Kormos (1954) determined the level of light pigment in red fruited progeny of a cross red X yellow. Action of the gene pairs YY^+, $C_1C_1^+$ and $C_2C_2^+$ was supposed to be involved in the production of different shades of colour. The following gene pair systems were postulated for the colour mentioned against each.($Y^+C_1^+$ = red ; Y^+C_1 = Salmon red ; Y^+C_2= pink; YC_1^+ = orange ; YC_1 = Lemon colour ; YC_2 = Ivorywhite)Brown and green, mature fruit colours are controlled by recessive chlorophyll retainer gene C_1 in combinations with Y^+ and Y. With C_1 present, Chlorophyll remains as the fruit matures. When C_1 combines with Y^+ (Salmon red) a brown mature fruit colour results. With Y (Yellow) a yellowish or olive-green colour is produced (Smith, 1948, 1950 ; Kormos and Kormos, 1956).

Brauer (1962) analysed B-carotene in mature fruits of chillis and proposed action of the gene B and T for high carotene content. The gene G is no doubt synonymous with "C_1". With the anthocyanin gene "A" present in AA BBC_1C_1tt genotype,

mature fruits when dried appeared nearly black (Brauer, 1962). This could account for the domination of black fruit colour noted by Halsted et al., (1908). Cano trait, characterised by yellowish white spots on the skin of the mature fruits, is controlled by a single recessive gene (Palacio and Ramos, 1977).

Chalkova et al., (1985) made an objective evaluation of the fruit colour of pepper (Capsicum annuum) cultivars. Conard et al. (1987) did the evaluation of two methods of pepper fruit-colour determination.

Milkova et al. (1985) proved that the mode of inheritance of colour of flower of Capsicum annuum is multigenic and additive.

3.3.7 Inheritance of vegetative characters :

Gomej et al (1987), showed that the character, like the plant height, length of mainstem, length of first three internodes, were additive and polygenic. They also found a partial dominance of greater plant height and larger internodes. But in some cases the plant height and internode height werefound to exibit maternal influence.

3.3.8 Total yield :

Singh and Singh (1970) found fruit yield positively correlated with number, length and width of berries and with

thousand seed weight and showed low heritability estimates. Nandpuri, Gupta and Thakur (1970) also found fruit weight per plant being positively correlated with 100 seed weight, fruit size, number of fruit, number of branches per plant and plant height. Nandpuri Gupta and Thakur (1971) observed high heritability estimates for the fruit yield of a single plant. High combining ability was noted by Betlach (1973). Lee (1976) found yield to be influenced directly by the number of fruits per plant. C. annuum showed overdominance for total yield (Thakur, Gill and Bhagchadani, 1980) while the non-additive component of heritability was found to be higher than the additive component (Khalfallah and Abdel-al, 1975; Singh and Singh, 1982). Singh and Singh (1978b) had earlier shown heterosis for total yield in intervarietal crosses.

Enhanced fruit size and seed set in Capsicum annuum by use of naphthalene acetic acid treatment was reported by Hariharan et al., (1984).

Mccraw et al (1986) reported effect of transplant age and pruning procedure on yield and fruit set in bell pepper (Capsicum annuum). Aiyelaagbe et al., (1987) found that sawdust, drygrass, maize cob mulches, applied to chili plants, significantly enhanced vegetative growth

and fruit yield. Shifriss et al (1987) reported segregation in twelve pairs of characters in Capsicum annuum eg. anthocyanin pigmentation in the cotyledons was controlled by a single recessive gene and pigmentation was independent of the resistance to potato virus. But in some cases this pigmentation was dominant and was polygenic in those cases where it was linked with the male sterility genes.

3.3.9 Number of locules in pistil :

No exact interpretation is known but multilocular fruits were present in F_1 plants obtained from a cross of a multilocular variety with a bilocular variety (Barnes, 1942).

3.3.10 Number of seeds per fruit :

Bell pepper, California Wonder, showed greatest number of seeds per fruit (Arya and Saini, 1976). The inheritance of seed number in pepper hybrids was found to be overdominant and independent of ovule number. Hybrid flowers had high seed number and higher number of ovules (Popova, Mikhailov and Yazova, 1979).

3.3.11 Early or late seed germination:

Hybrid between early and late emerging cultivars showed partial dominance for slow emergence at low temperature and both additive and dominant gene action (Randle and Honma, 1980).

3.3.12 Erect fruit position :

Ramanujam and Joshi (1965) reported that this character is controlled by a single gene.

3.3.13 Plant height :

This character showed overdominance in C. annuum (Thakur, Gill and Bhagchadani, 1980). But Singh and Singh (1976a) had earlier reported negative heterosis. Milkova (1977) showed general and specific combining ability in pepper for plant height. But Singh and Singh (1978b) have reported heterosis in intervarietal crosses for the height of the plant.

3.3.14 Fruit Shape : Yagishita and Hirata (1987) reported graft induced change in fruit shape in Capsicum annuum L.

3.3.15 Branch Number :

Non-additive gene effect was recognised by Awasthi, Joshi and Ghildiayal (1976) but Milkova (1979) had reported both additive and non-additive gene effect in diallele crosses. According to him some varieties showed additive effect while others showed non additive effect.

3.3.16 Stem colour :

The stem colour of C. frutescens (green or purple) is controlled by a single dominant gene (Ghai, Gill and Singh, 1972).

3.3.17 Leaf number :

This charater also showed additive gene effect in some varieties and non additive gene effect in other varieties.

3.3.18 Leaf Colour :

Purple leaf colour is dependent on a dominant inhibitory gene (Ramanujam, Joshi and Rao, 1965) . Ghai, Gill and Singh (1972) hold that purple colour of leaf in C. frutescens is controlled by a pair of complementary genes with a third causing variegation.

3.3.19 Calyx condition :

Non-enclosing calyx is represented by C as opposed to enclosing type of calyx (Deshpande, 1933; Lippert et al., 1965). The base and calyx characters are interdependent upon each other rather than being linked (Peterson, 1959). Closed flower trait in C. annuum is controlled by a recessive gene (Subramanya and Ozaki, 1984).

3.3.20 Pubescence :

Pubescent condition of the stem, petiole and leaves appears in the ratio of 15:1 (Duplicate factor gene interaction) with individuals of the dominant hairy class showing different degree of pubescence (Ikeno, 1916). But Holmes (1934) held smoothness of the stem to be a dominant character.

3.3.21 Flower :

Tanksley et al.(1984)proved that multiflower character in Capsicum is controlled by 5 genes in Capsicum chinense which can be transferred to Capsicum annuum making every one of its branch to produce multiple flowers and fruits.

3.3.22 Days to flowering :

High heritability estimate was reported by Nandpuri, Gupta and Thakur (1971). Additive dominant and environmental variation was found to control this character by Singh and Singh (1976a). Medium heritability estimates and dominant gene effect for days to flowering were observed by Thakur, Gill and Bhagchadani (1980) in C. annuum.

3.3.23 Days to maturity :

Earliness appears to be due to several dominant or partially dominant genes (Barnes, 1942; Odland, 1948). Nandpuri Gupta and Thakur (1971) showed high heritability estimates. A cross between C. annuum and C. pendulum showed good combining ability for earliness (Daskalov, Rusenova and Milkova 1973; Betlach, 1973). California Wonder was found to be latest maturing of all bell-peppers (Arya and Saini, 1976). High degree of non-additive gene action was reported by Khalfallah and Abdel-al(1975). Additive dominance and environmental variance

in varying proportions, in peppers, was found by Singh and Singh (1976a). Earliness was found to be influenced by both additive and nonadditive effects (Thakur, Gill and Bhagchadani, 1980).

3.3.24 Detachment force for the fruit :

This was found to be controlled by a number of effective factor behaving as additive genes (Werner and Honma, 1980).

3.3.25 Resistance to mosaic virus :

Ramanujam and Joshi (1965) found it to be controlled by a single gene linked, in repulsion phase, with a gene for erect fruit position and is independent of leaf, petal and immature fruit-colour genes.

3.3.26 Stomatal frequency :

Stomatal frequency in peppers in influenced independently by both paternal and maternal genotypes (Silvetti, 1981).

3.3.27 Right and left handed phyllotaxy:

The plants are classified into left-handed and right-handed respectively according to the clockwise and counter clockwise spiralling arrangements of their alternate

leaves around and up the main stem. The total yield of fruits in terms of both fruit-weight and number of fruits was higher in right-handed than in left-handed plants. This suggests that regulation of foliar spirality is genetic and can perhaps be used to advantage for increasing the productivity with alternate phyllotoxy (Bible, 1976).

3.3.28 Vit C. content of fruits :

Sathe and Phadnavis (1977), studying 26 red-pepper forms, found var. 70-1-1 had highest Vit. C content per fruit. This character was found to be positively correlated with fruit length. Pankar and Magar (1978) found Vit.C 38-86 mgm/100gm of fresh whole chili. Keshinro and Aketiku (1983) studied Vit.C content of both fresh and dried fruits of varieties and two spp. of chili, and found in C. frutescens 4.6±0.3% in dry samples to 55.7±7.5 mgm/100 gm in fresh fruits.

3.3.29 Vit E. Content of fruits :

Kanner et al. (1979) studied the alpha-tocopherol (Vit.E) content of the fruits of pepper (C. annuum). It was found to contain 9 to 10 mgm of the substance per gm of its oil (olea resin). Alpha-tocopherol content of fresh and dried peppers depended upon the content of lipid which in turn depended upon ripening stage and genetic constitution of pepper. In the fresh fruit it was about 3 to 10 mg/100 gm and therefore

chili can be a very important source of Vit.E.

3.3.30 Capsaicicine content of fruits :

Pungent nature of Capsicum fruit is due to the presence of an alkaloid capsaicine (Thresh, 1876; Nelson, 1910). Together with capsaicine, dihydrocapsaicine non-dihydrocapsaicine and aflotoxins are also present (Sagara et al., 1980; Seenappa and Kempton, 1980). Secretory cells present along the placenta produce the alkaloid (Ohta, 1962b). Capsaicine-content varies from variety to variety and even from plant to plant as it is readily influenced by soil and particularly climatic conditions (Erwin, 1932; Miller and Fivreman, 1937; Brauer, 1962; Ohta, 1962b) This is controlled by a single dominant gene (Webber, 1911; Deshpande, 1935; Ramaiah and Pillai, 1935; Odland, 1948; Greenleaf, 1952; Ohta, 1960. Quagliotti and Ottaviano (1967) had made the physiological and genetical studies of pungency in chilis under various growing conditions and of its variability in different cultivated populations. Gill, Ghai and Singh (1973) hold that amount of capsaicine in C. annuum and C. frutescens is polygenically controlled and negatively correlated with shape index of fruits. Kvachadze (1976) studied F_1, F_2 and F_3-generations of a chili hybrid and showed that F_1 had intermediate amount while F_2 and F_3 generations had a range of variability of capsaicine content, within the limits of parental variability. This indicates that capsaicine content is a quantitative character resulting from the action of multiple genes. Sathe

and Phadnavis (1977) found red pepper variety 207-9-2 had highest capsaicine content among the 26 red-pepper varieties studied, and capsaicine content was negatively correlated with fruit-length.

El-Gherbawi (1977) found that capsaicine develops in fruits in the fourth week after fruit-set. Varieties differ in its content. Marshall and Doperalski (1981) studied the quantity of capsaicine in peppers and found it variable e.g., 1.01, 1.11 and 1.23 mgm/gm dried pepper while Wood-bury (1980) found it only 100-700 ppm.

Jurenitsch, Kubelka and Jentzsch (1979) studied cultivated varieties of Capsicum annuum , C. baccatum, C. pubescens, C frutescens and C. chinense, and tried to identify the composition of pungent principle (capsaicinoid). Mc Leod et al. (1979a) studied purple flowered Capsicum and located 25 loci coding for 15 proteins. He proved that C.tovari should be treated as a separate species while C cardenasii and C. eximium should be recognised as single biological species and C. pubescens should also be maintained as a separate species belonging to the same species complex, on the basis of the study of capsaicine contents.

Aleshin et al.(1974) studied albumin content in the ripe and germinating seeds of parental lines and heterotic hybrid of red pepper.

3.4 Mutations and Mutagenesis:

Much work,in peppers, has been done during last twenty years on detection of spontaneous mutations and induction of mutation using physical mutagens, chemical mutagens and a combinations of the two, leading to male sterility, female sterility and many meiotic abnormalities. A brief summary of this work is being given here.

3.4.1 Spontaneous mutations :

Occurrence of following spontaneous mutations has been recorded in some chili plants. Lippert and Bergh (1964) recorded the occurrence of variegated seedling mutants in chilis. On the basis of crossing studies, he found that this character is governed by multiple alleles. Bergh and Lippert (1964a) recorded the occurrence of six mutant genes in pepper, Capsicum annuum viz., female sterile (fs), spinach (sp) and branchless (bl) have been found to be completely female sterile, while three others, glossy diminutive (gd), scabrous diminutive (sd) and wallow leaf (wl) produced a few viable seeds. All showed foliar deformations (except 'fs') and much reduced branching or no branching. The genes, "fs" and "sd" reduced viability, though pollen fertility was normal for all mutants except "spinach". Pahlen (1967) discovered a new spontaneous mutant of pepper C. annuum which was called

"fasciflora". He also showed a female sterile mutant with marked increase in the number of floral components, governed by a single recessive gene, with pollen viability of 27-55%. Murty, Rao and Murty (1967) have reported an abnormal female sterile narrow leaved mutant. It had a dwarf compact and bushy habit possessing linear-lanceolate, narrow and sessile leaves. There was no seed-set inspite of profuse flowering. Meiosis had many irregularities like clumping of chromosome, uneven separation, lagging chromosomes and univalents. Tal and Shifriss (1974) reported abnormal behaviour and leaf anatomy in a scabrous, diminvtive and wilty mutant of C. annuum , produced as result of spontaneous mutation in a single gene. Greenleaf and Hearn (1976) have recorded a roundleaf mutant in "Bighart" pimiento pepper. Benzioni and Tal (1978) have recorded a scabrous diminutive and wilty mutant of pepper, in which the ability of roots to absorb and accumulate Rb^+ and K^+ ions was impaired. Pollak (1982) has described the rate of mutant substitution in populations with overlapping generations. Rao, Raja and Kumar (1983) have described the cytogenetics of a spontaneous desynaptic mutant in chili which showed reduced number of chaismata and pollen fertility. This condition showed a monogenic inheritance. Bengtsson and Christiansen (1983) described

the A_2-locus mutation and gave itsevolutionary implications.

3.4.2 Mutagenesis :

It is most suitable method for making alterations in genotype, to enlarge the variability of qualitative and quantitative characters, in shortest possible time and provides a good scope for selection because the variability has been narrowing in peppers due to unidirectional selection and limited type of germplasm. Discovery of different mutagens has increased the variety and kinds of mutations which can now be induced. Varied available chemicals, relative ease of application and low cost has made, artificial induction of mutation an important tool in plant breeding programmes. Physical mutagens like UV rays, gamma rays and X-rays have been used effectively to induce mutation. Chemical mutagens like diethyl sulphate (DES), ethyl-methane-sulphonate (EMS), dimethyl-sulphonate (DMS), nitroso-N-methyl-urea (NMU), nitrosc-N-ethyl-urea (NEU), ethyl-imine (EI), caffeine, methyl-nitro-nitroso-guanidine (MNNG), methyl-guanidine (MG), glutathione (G), 5-nitro-acenapthene (NA), nitroso-methyl-guanidine (NMG), hydroxylamine (HA), N-methylmaleimide (NMM) and N-ethylmaleimide (NEM)etc. are most effective chemical mutagens and have given most wonderful results.

3.4.2.1 Mutagenesis using physical mutagens :

Gamma-rays, X-rays and ultraviolet rays have been used to produce mutants in pepper.

3.4.2.2 X-rays mutagenesis :

Kamaluddin and Abraham (1970) described that X-ray irradiation of the seeds of chilis resulted in morphological abnormalities, chromosomal aberrations and production of chlorophyl -mutants with increased frequency e.g., ("xantha" mutation).

Terzyan and Saakyan (1972) described effect of X-rays on variation of pepper plants in M_1 generation.

Nagalla and Nagalla (1977) described the desynapsis in Capsicum after treatment with x-rays and EMS , variable number of univalents were found at diakinesis and metaphase Ist and chiasmata frequency was lower than that of normal plants.

Subhash and Nizam (1977) reported the meiotic abnormalities in M_1 generation like multivalents, fragments, bridges and multispindle formation after the C. annuum seeds were irradiated with X-rays.

Abraham and Koshy (1979) described mutagenic potential of green chilis and abnormalities like achromatic gaps,

chromosomal breakages and chromosomal clumping in the treated cells.

Subhash and Venkatrajam (1983) described the cytological and morphological variation induced in Capsicum cultivar C-5 after x-ray irradiation of 1,3,5 or 10 Kr. Gross chromosomal abnormalities were observed eg., unoriented fragments at metaphase, bridges at anaphase and telophase , with or with out laggards of the chlorophyll mutants also increased.

Venkatrayam and Subhash (1984) a Induced mutations in Capsicum annuum by using aqueous solution of mitomycin 'C' for different periods of time and found variations in both positive and negative directions for many quantitative characters such as plant height, number of branches, days to flowering, number of fruits etc. in M_1, M_2 and M_3 generations.

Venkatrajam, Devdas and Subhash (1985), treated soaked seeds of chilis with x-rays and treated them with 0.1 % EMS, separately and combining the both, obtaining 6 types of chlorophyll mutants namely xantha, albina, chlorina, viridis, maculata, and striata were recovered in M_2 generation. Occurence of chlorophyll mutations were in proportion to the dose durations and combined treatment enhanced the frequency of mutation.

Venkatrajam, Sadanandam Devadas and Subhash (1984), found the effect of mitomycin on soaked seed. It reduced drastically the percentage of seed germination and seedling survival. Mutants showed chromosomal alterations,Chlorophyll mutations, formation and development of micronuclei. Stickiness and clumping of chromosome also resulted in to - high pollen steribity.

Rao, Harini and Kumar (1987) studied colchicine induced mosaicism in chili pepper, and found that pellen fertility was reduced to nearly 5%. Univalents and laggards were commonly observed, together with the breakdown of spindle.

3.4.2.3 UV -ray mutagenesis :

Chassagne, Gaudillere and Monties (1981) have described the effect of UV-radiation on chili plants grown under natural and artificial lights. These plants showed shorter stem and increased phenolic content of leaf.

3.4.2.4 Gamma-rays mutagenesis :

Daskalov (1973b) studied the induction of mutations in C. annuum by irradiating seeds with gamma-rays.

Daskaloff (1973a) has induced mutations in pepper and a male sterile mutant, thus produced, was used to produce hybrid seeds.

Daskalov (1973a) described a male sterile mutant of C. annuum, isolated following seed irradiation with 13.5 Kr gamma-rays.

Daskalov (1975) described the production of albina chlorophyll-mutant for early and midearly production using gamma irradiation.

Ilieva and Molkhova (1975) studied the microsporogenesis in Capsicum annuum, after it was irradiated with 0.3, 0.5, 1.0 and 1.5 Kr of gamma rays, with 1 and 1.5 Kr showing blockage of meiosis at early prophase in 1-2% PMC. The chromosomal aberrations were seen at low dosage, 47-72% with 0.3 Kr and 87-98% at 0.5 Kr and at 1 and 1.5 Kr all PMCs were damaged. He also found that fragments and bridges developed even at low doses of exposure, Sethupathi, Ramlingam (1977) described mutants of chili, obtained from a population of M_2 generation after treatment with gamma-rays. Khuspe and Ugale (1977) found gamma irradiation from ^{60}Co more effective than EMS (0.1-0.31%) in delaying flowering but weight of 100 dry fruits increased with irradiation dose. "Mohot" variety produced heaviest seeds when treated with 10 Kr and 20 Kr gamma rays but "C.A. 452" variety showed heaviest bearing with 0.2% EMS. Katiyar (1978) reported the meiotic abnormalities and pollen sterility of M_1 and M_2

generations of the Capsicum plants obtained from the seeds irradiated with 5,10 or 15 Kr. They showed abnormal chromosomes, stickiness, clumping, breakages, bridges, unequal segregations, laggards and abnormal microspores, Pollen sterility increased with increase in radiation dosage.

Maltseva (1978a) irradiated seeds of pepper with low doses and sowed them in glass-houses as well as in fields. The highest effect was noted in glass-house conditions as it gave early and higher yield.

Maltseva (1978b) described the action of gamma-irradiation (1.2-1.8 Kr) using ^{60}Co on the seeds of three pepper species. It resulted in a more rapid development of plants, and early flowering and appearance of ovaries which were early- ripening. Illieva and Molkhova (1979) studied effect of gamma irradiation of 0.3 to 2.0 Kr at various stages of flowers-bud development and showed that degenerative changes were established in pollen grains e.g., multinuclearity, absence of nuclear differentiation, variations in the number of pollen pores, out growth of exine, incomplete maturity of generative nucleus and varying extent of cytoplasmal vacuolization. Greatest degenerative change was observed following the treatment at the early stage of another development. If the pollen grains were irradiated

with 2 to 3 Kr doses, degenerative changes were found in embryo and endosperm also. Maltseva and Moinova (1980) described the effect of irradiation on pepper seeds. It resulted into intensive growth of plant and higher index of early ripening. This was found to be result of higher ascorbate oxidase activity in plant leaves. Biacs and Gruiz (1980) described the effect of gamma irradiation on the lipid composition of paprika, black pepper.

Daskalov and Maltseva (1980) reported the results of irradiation of pepper seed with gamma rays and found that low radiation doses stimulated seed germination and early maturation.

Rao and Lakshmi (1981) described the meiotic abnormalities of gamma-ray induced mutants of C. annuum after the use of 10, 30 or 40 Kr. It resulted into meiotic abnormalities and pollen sterility. Meiotic abnormalities, induced, were stickiness of the chromosomes, clumping, formation of multivalents and univalents, breakages, non-orientation of chromosomes at metaphase-plate, unequal groupings of chromosomes, laggards and abnormal microscopres. The frequency of occurrence of these abnormalities was proportional to the doses of the gamma-rays and pollen sterility was cumulative

result of varient and aberrant meiotic stages. Mukhopadhyay and Mookerjee (1981) described effect of gamma irradiation on deoxyribonucleiohistone binding.

Makedonov and Tarasov (1982) conducted direct experimental study of mutagenesis of two single stranded breaks located within the isolocus of sister chromatids in the strands of same polarity. Efficiency of induced mutagenesis was very high.

Henner et al., (1982) studied the site and structure of gamma-irradiation-induced DNA-breakages, by irradiating with doses of 2.5-20.0 Kr. The amounts of induced DNA-breakages were proportional to the radiation doses.

Josimovic(1983) has described some chemical changes in the irradiated pepper.

3.4.2.5 Chemical mutagenesis :

Kalovkyan (1968a) made a study of cytological changes in C. annuum under the effect of chemical mutagens e.g.,NMU, NEU and found the proportion of fragments and bridges depended upon the dose of mutagen.

Kalovkyan (1968b) used EI, NMU, NEU, in different concentrations for different periods of time on sweet-pepper

varieties A-60 and Nov-35. Many heritable changes were dominant mutations. He also showed many irregularities of chromosomes in pollen-mother cells of the plants of M_1 generation. Markus (1968) sprayed 2-3-dichloroisobutyrate on pepper and induced male sterility. Galukyan (1969) reported different types of morphological variations induced by EI, NMM, NEU and NEM in M_1, M_2 and M_3 generations of pepper. Pöchard (1970c) induced male sterility by using EMS and gamma irradiation.

Zubrzycki and Pahlen (1970) found EMS to be more efficient in inducing chlorophyll mutation. Zderkiewicz (1971) reported variation in the growth, size, weight of fruits and in capsaicine content when pepper plants were treated with EI and different irradiations. Videnin and Skripnikova (1971, 1972) found a wide spectrum of mutations in tall-habit, branching and in number, size and position of fruits, using EI, EMU, DES. Dwarfed, malformed and early ripening forms were isolated, and several strains showed early ripening and gave higher yield. Batikyan and Galukyan (1971) found NMU to be more effective than NEU and EI in inducing mutations. Skripnikova (1973) reported a reduction in germination and survival rate and many other variations in M_1 generation. Daskalov (1973b) obtained male sterile mutants. Solomatin (1973) showed that frequency of morphological changes in M_1 varied with the

variety from 1.8% to 10.0% on being treated with NEU, EI and DMS, with NEU showing highest change. Bansal (1973) isolated sterile mutants from EMS and NMU treated populations. Solomatin (1976) reported variation in mutation frequency from 71.5 to 86.0 %, 58.0 to 65.2% and 51.0 to 60.0% in EI, NEU and DMS treated populations respectively.

Chauhan and Kinoshita (1980) have reported the chemically induced male sterility in Capsicum annuum.

Gukasyan and Akopyan (1975) obtained mutations in colour, shape, and size of leaves and fruits. Largest number of mutations were obtained at 0.05% dose level of NMU. Solomatin (1976) also found increased variation in the yield in M_3 lines of EI, NEU and DMS treated populations. Skripnikova (1976) isolated some economically useful mutants of pepper, obtained from the populations treated with low doses of NEU and DMS. There were isolated early maturing, large-fruited, multifruited and compact forms, from the population treated with 0.01%, 0.005% and 0.025% concentration of EI, DMS and NEU respectively. Rate of mutation was found to have increased with the increase in the dosage of the mutagens. NEU showed highest rate of mutation. The dosage used for NEU was 0.025% and 0.012% for EI it was 0.01% and 0.005% and many concentrations of DMS were used. Gukasyan and Tumanyan (1976)

observed increase in the frequency of aberrant cells in M_1, M_2 and M_3 generations of population treated with NMU. Morphological variations like induced suppression of apical dominance and of primary branching and variation in the number of petals and stamens were reported in plants treated with both gamma-rays and EMS. Sethupathi Ramlingam(1976) also reported occurrence of aerial roots on the basal portion of stem. He isolated two such sterile mutants from NEU and EMS treated plants which produced flowers and alboviridis chlorophyll mutation in M_1 population treated with gamma-rays and DES.

Subhash, et al. (1981a) reported induction of multilocular ovary in C. annuum by treating it with mitomycin 'C'. 'Dimitrov (1981) studied the nature of chromosomal gaps induced by alkylating reagents (EI, N-nitroso-N-methyl urethane) and X-rays in C. capillaris which became apparent after treatment with caffeine. Koornneef (1981) studied the complex syndrome of ttg-mutants. Olson and Cumming (1981) studied dosimetery and Haber's rule for calculation of proper doses of chemical mutagens. Sadanandam, Kumaraswamy and Subhash (1981) reported occurrence of desympatic mutants in C. annuum induced by treatment with 0.19% EMS. Danilenko (1982) described the mutagenic activity of nitroso-methyl-uridine. Ackermann et al. (1982) described the reaction of a mutagen (1,1, hexamethylene-bis [5-p-chlorophenyl-C-biguanide] with guanosine and

cysteine. Singh (1982) described the effect of IAA with maleic hydrazide and colchicine on the root tip-mitosis. It resulted into chromosomal abnormalities like chromatid-breakages, bridge-formation, polyploidy, lagging chromosomes, micronuclei, stickiness etc. Sadanandam and Subhash (1983) isolated desynaptic mutants from a DES-treated population of C. annuum. It was partially sterile (72% pollen sterility). It was monogenic and recessive.

Goodman et al., (1983) has described the enzymatic basis of mutagenesis by manganese. Ohta et al., (1983) has described the formation of mutagens by reaction of nitrite with several tryptophan-decomposition-products resulting from acids hydrolysis of proteins. Mccoy et al., (1983) described the mutagenic specificity and prediction of mechanism and bioactivation pathway of genotoxicants e.g. , 5-nitro-acenapthene. Venkatrajam, Sadanandam and Subhash (1984) described mutagenic effect of mitomycin 'C'(MC) on soaked seeds of C. annuum. It showed significant reduction in germination and seedling survival percentages, chromosomal aberrations in meristematic cells and production of six chlorophyll mutants, "Alkyla", "Xantha", "Chlorina ", "Viridis", "Striata" and "Maculata" in chili.

3.5 Heterosis :

3.5.1 General

Koelreuter (1766) was first to observe hybrid vigour in the interspecific hybrids of Nicotiana. He observed that "the vigour of a hybrid was related to the degree of the genetic dissimilarity of its parents". 146 Years later* East and Hays(1912) confirmed the role of genetic diversity in the expression of hybrid vigour. But it was Shull (1948 and 1952) who put forward the idea of commercial exploitation of hybrid vigour in corn.plant. Shull asserted that hybrid vigour was associated inevitably with heterozygosity and deterioration with homozygosity. He proposed the term of "Heterosis" to describe the vigour of heterozygous hybrids. Many other workers during this period observed the phenomenon (Knight, 1799; Naudin, 1865;Beal, 1880 ; Shull, 1910; East and Hayes, 1912) Later on several theories were put forward to interpret this phenomenon (Dominance theory and Overdominance theory).

Heterosis may be observed in any part of the plant in the form of vigour, early maturity, height, increased productivity, both in number of fruits and total wt. of fruits and seeds, size of the fruits, size and number of the branches etc. (Deshpande, 1933; Pal, 1945; Martin, 1949; Fujii et al., 1959).

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* See Thompson 1949.

3.5.2 Heterosis in chilis :

Deshpande (1933) was first to observe heterosis in chili, C. annuum in India. F_1 hybrids showed general vigour, early maturity, increased height and productivity in terms of total number of fruits or total amount of dry weight of fruits. Pal (1945) also observed that hybrids between two Pusa type chilis gave higher yield, matured early and produced fruits thicker than those of the parents. Greenleaf (1947) discussed the importance of heterosis in Pimiento pepper and suggested that parental lines should be selected on the basis of vigour, fruit size and high yielding capacity. Michna (1968) reported heterosis in the quantity of capsaicine and the amount of dry matter in the yield. Marfutina (1969) also reported positive heterosis in pepper. Popova and Mihailov (1970) noted larger embryos and higher weight of the embryos in hybrids. Hybrid vigour in earliness of the fruiting and quantity of the yield were also reported by Silvetti and Giovanelli (1970). Michalek (1971) found that hybrids have higher yield as well as higher resistance to diseases. Nagaich et al. (1972) made many interspecific crosses and found hybrid vigour in respect of fruit number, plant height and total yield. Popova (1971) reported heterosis in earliness of fruiting and total yield which increased by 40.1% in fresh weight and 14.9% in dry weight over their parents. Total yield of fruit was 35.5% higher in the hybrids. Alpat, Ev, and Khrenova (1970) found that earliness, yield, brighter

fruit colour, greater fruit diameter, longer length of fruit, greater thickness of pericarp and higher content of ascorbic acid were dominant characters present in hybrids. Studentsova (1973) reported heterosis in the earliness of fruiting and yield. Gill et al., (1973) found the hybrids with very high yield. Hybrids with higher yield were also reported by Marfutina (1973). Dikii et al., (1973b) crossed mild and pungent varieties and observed heterosis in earliness of fruiting and yield. Attavar and Bhat (1973) reported hybrid vigour in yield. Manikantannair and George (1973) studied intervarietal crosses in chilis and found hetorosis in ascorbic acid, sucrose and capsaicin contents in hybrids. Singh et al., (1973) made many crosses and reported heterosis in plant height, fruit number and fruit length. Popova (1973) found hybrids with higher yield, better biochemical properties and good adaptibility. Popova and Mihailov (1974) reported hybrid vigour in vegetative growth, large number of flowers per plant, fruit number, fruit weight and number of seeds. Lippert (1975) reported hybrid vigour with regard to dry fruit weight, fruit length and percentage of mature fruit at harvesting time. Bak et al. (1975) hybridized 48 varieties of C. annuum and heterosis was reported in vigour, early maturity, fruit number, fruit length and yield which was 60% higher than that of parents.

Ilyushchenko (1975) reported increase in sugar content of hybrid seeds. Alpat'EV, and Khrenova (1975) observed hybrid vigour in earliness of maturity, height of plants, light colour of leaves and fruits, large size with high yield and thick pericarp. Soh et al. , (1976) reported hybrid vigour in number of days from sowing to flowering in diallelic crosses. Markova et al., (1976) found hybrids with higher protein content than those of parents. Popova and Mihailov (1976a) observed heterosis with regard to size of embryos, height of plant, number of leaves, area of leaf surface, length of shoots, length of roots which became apparent immediately after fertilization. Mishra et al., (1976) observed heterosis in fruit length and number of primary branches. Milkova and Daskalov (1977a) reported heterosis in earliness of fruit maturity. Singh and Singh (1977 a) found hybrids vigour mostly for non-edible and seed portion. Popova (1978) found pollen germination, pollen viability and number of seeds larger in hybrids than in parents. Uzo (1984)found heterosis with regards to plant height, median harvest date, number of fruits and total fruit weight per plant but not for leaf area and fruit size in the intervarietal hybride of C. annuum.

Popova and Mikhailov (1975) showed that in sweet garden pepper hybrid vigour expresses itself in the weight of

fresh and dry plants, height of plants and average number of leaf. It also expressed in the volume and length of root system and the length of embryo. Singh and Singh (1976e) have reported in C. annuum hybrid vigour in F_1 and inbreeding depression during selfing in hybrid population. In some cases there was a positive heterosis for nonedible and seed portion. But in other hybrids, these chracters showed negative heterosis. In nonedible seed characters, additive and nonadditive gene action were present.

Kumar and Rao (1986) reported the heterosis in the intervarietal F_1 hybrids of different cultivars G_3 x G_4 of Capsicum annuum in respect per plant and number of seeds per fruit. Meshram and Mukewar (1986) reported heterosis in intervarietal hybrids of Capsicum annuum for days to flower, plant height, number of primary branches, fruit length and number of fruits per plant. The hybridization was done with the help of male sterile varieties. Result showed the yield of F_1 hybrids nearly 157 percent of

the yield for superior variety (SP) , Krishnakumar and Peter (1986) reported significant heterosis for plant height, days to first harvest, days to maturity, fruits per plant, green fruit yield per plant, seeds per fruit and seed per plant in 10 inter specific hybrids obtained from a cross Capsicum annuum X Capsicum frutescens. Nair et al (1986) reported heterosis in the intervarietal hybrids of Capsicum annuum for over mild parent values for different trait as number of branches, Vitamin C content, number of days for blooming and number of seeds per fruit.

3.6 Polyploidy

3.6.1 Spontaneous and induced polyploidy:

Induction of polyploidy is a handy tool in increasing the variation of a gene pool. Colchiploidy in paprika pepper was first reported by Gyorffy in 1939, while spontaneous tetraploids in C. frutescens were reported by Greenleaf (1947). Many workers have reported this phenomenon all over the world (Pal and Ramanujam, 1939; Nishiyama, 1939,1940; Pal et al., 1941; Aleksic, 1960; Palfi et al., 1961; Siskovic,1962; Raghuvanshi and Joshi, 1964; Palfi et al., 1967; Murthy et al., 1968; Indira and Abraham, 1978 ; Khan and Siddiqui,1981). Toole and Bamford (1945) reported the formation of diploid plant from haploid pepper. Indira and Abraham (1977) also found, for the first time a tetraploid plant of C. annuum by irradiation.

Triploids have been found to arise spontaneously from colchicine treated seeds (Pal and Ramanujam, 1939). Pochard and deVaulx (1971) reported occurrence of a haploid pimiento pepper plant. Later on Chennaveeraiah and Habib (1973) reported spontaneous occurrence of triploid in C. annuum. Nishiyama and Karasawa (1954) produced triploids in Capsicum by crossing diploids (2x) and tetraploids (4x) reciprocally. Ohta (1962b) obtained hypotriploid (2x = 35) in Capsicum by crossing 2x and 4x plants. Indira and Abraham (1980) reported the occurrence of radiation induced triploidy (3x) in C. annuum. Alonso and Kimber (1981) described meiosis in triploid hybrids of pepper and determined its relative affinity, while Kimber and Alonso (1981) described the same for tetraploid hybrids.

Panda, Aniel Kumar and Raja Rao (1984) reported the occurrence of induced octaploid in chili pepper (C. annuum cv. 'cerasiformis') by using colchicine. As compared to tetraploids these octaploids were less vigorous, suggesting that the optimum and desirable ploidy-level for Capsicum is probably tetraploid association. In octavalents, hexavalents, pentavalents and trivalents, diakinesis and metaphase I showed high irregularity. Pollen and seed fertility was very low.

3.6.2 Characteristics of Polyploids :

Polyploids were generally found to gain in plant height number of leaves, size of the cells, number and size of stomata, size of flowers, pollen grains and seeds as compared to those obtained from diploid plants (Greenleaf, 1947; Georgieva, 1959; Aleksic, 1960; Pal et al., 1941). But Murthy et al. (1968) and Khan and Siddiqui (1981) have found tetraploid with decreased plant height and lesser number of branches. Selivanov and Tyrnov (1975) showed that the study of post radiation leaf necrosis can be used to diagnose the ploidy level of the pepper plant.

3.6.3 Aneuploidy :

Aneuploidy in pepper has been reported in a very few cases. Pal and Ramanujam(1940) reported an additional chromosome (trisomic, 2n+1) in Capsicum . Same phenomenon has been reported by Subhash and Nizam (1975) in C. annuum after X-ray irradiation. Pochard (1970d) also described the occurrence of trisomics in pimiento pepper obtained from the progeny of a haploid plant. Pochard (1977) studied 11 out of 12 possible primary trisomics in C. annuum, obtained from single haploid plant like pimiento without pungency. It was observed that some genes e.g. a gene of resistance to TMV and a gene for anthocyanin were located on specific chromosomes.

3.7 Hybridization :

3.7.1 General :

Hybridization is a very important tool for improving cultivated varieties. Through this process, desirable gene combinations can be obtained and useful genes can be transferred from one variety to another. In many cases, it also induces hybrid-vigour. Crosses have been done between C. annuum and C. frutescens to determine the degree of genetic relationship between them cytologically (Smith and Heiser, 1957a; Keshavram and Saini, 1971; Sahrigy and Seehy, 1974 , Pillai et al. 1977; Eshbaugh, 1978a ; Saccardo and Ramulu, 1978). Emboden (1961) made study of crossing relationship of C. baccatum. Angete (1967) cultivated many hybrid red pepper varieties. Shifriss and Rylski (1973) studied comparative performance of F_1 hybrids and open-pollinated bell-pepper under subtropical conditions.

3.7.2 Intervarietal hybridization :

Intervarietal hybridizations are made mostly for commercial exploitation of hybrid-vigour, estimation of heterosis, heritability estimates, determining combining ability and genetic advances etc. Many workers have made cytological investigations of hybrids along with the study of the morphological variations. They have reported meiotic

irrigularities like unequal chromosomal distribution, presence of laggards at different stages, bridges, quadrivalents, trivalents etc. These show reduced pollen fertility (Michna, 1971: Manikantan and George, 1973, 1975; Lorenzetti and Cirica, 1974; Sahrigy and Seehy, 1974; Sethupathi Ramalingam, 1974; Lakshmi and Baparao, 1977b; Dikkii, 1976; Khrenova, 1970). Lee et al., (1980) have studied a new hybrid cultivar of pepper produced with the help of male -fertile and male-sterile parents.

3.7.3 Interspecific hybridization :

Interspecific hybridization of sweet peppers has also been reported by Hirose, Nishi and Takashima (1960), Levori (1974) and Dikii (1976). These hybrids showed much higher yield as compared to their parents. Khrenova (1970) noted that maximum heterosis is present in only F_1 and F_2 generations of the hybrid peppers and not in later generations. Kvachadze(1976) studied hybrid chilis and found that capsaicin content and fruit form and size showed intermediate characters in F_1 generation. F_2 and F_3 generations showed variability within the limits of the variability of parental forms. It was also indicated that capsaicin content and fruit size were quantitative characters determined by the action of many identical genes. Zamir Tadmor (1987) reported unequal segregations of nuclear genes in the inter-specific hybrids of Capsicum, perhaps because of linkage.

3.8. Diseases of peppers, their control and resistance to diseases, pests and parasites :

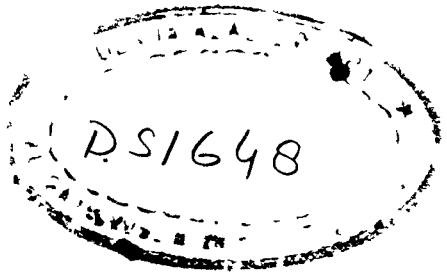
A survey of diseases, parasites and pests of chili is essential for drawing up a comprehensive resistance breeding programme. Recently much work has been done on the study of fungal, bacterial and viral diseases of peppers as well as of insect pests and nematode parasites. Resistance of peppers to these pathogens has also been studied together with the methods of their control. A summary of this work is being given here.

3.8.1 Bacterial diseases, resistance against them and their control :

Following is a brief summary of this work done on bacterial diseases of chili. Shekhawat and Chakravarti (1976) studied factors effecting development of bacterial leaf-spot of chili caused by Xanthomonas vesicatoria. They stated that there was a heavy infection during July, August and September when humidity was very high and temperature was between 22° and 34°C. Keshwal and Joshi (1976). studied the occurrence, in chili plants, of the infection by different strains of Pseudomonas solanacearum. Sowell and Demski (1977) reported the factors causing resistance in pepper against bacterial-spot disease. These resistant factors, against Xanthomonas vesicatoria, were

present in strains of Capsicum annuum, Capsicum chinense and Capsicum pendulum Shekhawat and Chakravarti (1978) described about the survival of Xanthomonas vesicatoria, the incitant of chili leaf-spot, and found that it survived for 14 months along with seeds at 8°C, and for 10 months at 10-38°C and bacterial suspension survived in autoclaved soil with 17% moisture content for 105 days at 8°C. But in unautoclaved soil it survived only for 15 days . Hayward and Moffett (1978) reported the leaf spot on Capsicum are caused by Pseudomonas solanacearum . Shekhawat and Chakravarti (1979 a) studied resistance of chili cultivars to bacterial leaf spot caused by Xanthomonas vesicatoria. One line 23-1-7 bk was resistant but did not set fruit while 'Jwala' was field tolerant. Woltz and Jones (1979) reported effect of magnesium on bacterial spot of pepper caused by Xanthomonas vesicatoria. Stall and Cook (1979) gave the evidence that the bacterial contact with the plant cell (in pepper) is necessary for the development of hypersensitivity reaction. Dahlbeck, Stall and Jones (1979) studied the effect of vertical and horizontal resistance on the development of the bacterial spot on pepper (Capsicum annuum) Dahlbeck and Stall (1979) studied mutation for the change of the race in the cultures of Xanthomonas vesicatoria. Shekhawat and

Chakravarti (1979b) described the comparison of agarplate and cotyledon -methods for the detection of Xanthomonas vesicatoria in chili seeds (Capsicum annuum and Capsicum frutescens) and they proved that cotyledon-method is more reliable as compared to agar-plate technique. Coplin(1980) observed the occurrence of soft rot disease of bell pepper caused by Erwinia carotovara and due to this fact washing pepper before packing increased amount of decay but decreased it if the washing water was chlorinated. Meadows and Stall (1981) described different induction periods for the development of the hypersensitivity in pepper (Capsicum annuum) to Xanthomonas vesicatoria and found that the induction-period was five hours after inoculation.Cook and Stall (1982) described different races of Xanthomonas vesicatoria, infecting the pepper, Capsicum annuum. They also described some sources of resistance to these pathogens. Bashan and Assouline (1983) devised a technique for the detection of Pseudomonas species infesting pepper. He, Sequeira and Kelman (1983) observed 29 strains of Pseudomonas solanacearum isolated from 14 cultivated and wild hosts including C. annuum. Stall and Hall (1984), described chlorosis and ethylene production in pepper C. annuum infected by Xanthomonas campestris, pathovar,"vesicatoria." They showed that chlorotic zone, surrounding necrotic lessions



of bacterial spot, is associated with ethylene production in diseased leaves. Cook and Guevara (1984). described the hypersensitivity in Capsicum chacoense caused by Xanthomonas campestris pv."vesicatoria." This hypersensitivity resistance was caused by a dominant gene. Jones, Arthur, Engelhard and Powell (1984) also described the bacterial leaf spot caused by Pseudomonas sp. Adaskaveg et al., (1985) found that many strains of Xanthomonas campestris pathovar 'vesicatoria' infected the pepper plants and some of their strains were tolerant towards copper and zinc salts generally but some of the strains were resistant to these salts. Marrero et al.,(1986); noted the response of the pepper varieties to the infection of Xanthomonas vesicatoria and found that 'California Wonder' was most effective while "Trunk Heart" 27A" were least effected,. They also noted that the extent of infection varied with the environmental conditions. Citaitis et al.,(1987) studied the infectivity of various species of Xanthomonas to Capsicum annuum and found that these inoculations induced infections of 38 percent of pepper plants. Hibberd et al (1987) studied the hypersensitivity resistance of chili cultivar against the infection of Xanthomonas campestries and found that early "California Wonder" and early "California Wonder 10-R." carry resistance genes against these infections namely Bs1 and Bs2. Akhtar et al (1987) studied the resistance of 8 red

pepper cultivars against the infection of Xanthomonas campestris variety 'vesicatoria' and found that 'Nilum' and 'Jalapeno' varieties were resistant and severity of the disease was high in pots as compared to that in the fields.

3.8.2 Viral diseases, resistance against them and their control:

Many papers have been published during the last thirty years on viruses, their detection, extent of infection, mode of transmission, morphological and other effects of infection on the host plant, the resistance to infection in hosts, its inheritance and methods of controlling these viruses.

3.8.2.1 Morphological effects of Viral Infections :

Awasthi and Singh (1974a) described the effect of cucumber mosaic virus on chili plants. Awasthi and Singh (1974b) showed the abnormalities in the cells of anthers and the production of non-functional pollen grains in C. annuum infected by cucumber mosaic virus. Kamra and Dubey (1975) studied the mosaic disease of chili and discovered that mottle, puckering, blistering and wavy leaf margin are produced in chilis due to the infection of this virus. Feranandez and Gaborjanyi(1976) found that the dwarfing induced in pepper,"California Wonder", undergoes reversion by the use of spray of polycarylic and gibberellic acids. Gaborjanyi and Fernandez (1976) could not induce alterations of peroxidase activities and of the growth of pepper C. annuum, 'California Wonder', plants when these

were inoculated by tobacco etch virus (TEV). Joshi and Dubey (1976) studied the effect of cucumber mosaic virus infection on the growth moisture and dry matter content of the chili strains (C. annuum) and proved that it adversely effected plant growth and moisture but increased dry matter. Lockhart and Fischer (1976) studied the effect of cucumber mosaic virus infection alone or in combination with potato virus Y, on pepper and found that it severely limited the yield of marketable pepper. Fernandez and Gaborjanyi (1977) described the effect of tobacco etch virus infection on cultivars of C. annuum, e.g. California Wonder etc. Burgyan et al. (1978) studied the symptoms of tobacco mosaic virus infection on peppers and other plants. Sutic et al.(1978) studied necrosis of pepper cultivars caused by infection of tobacco mosaic virus. Cordrey and Bergman(1979) described the influence of cucumber mosaic virus on growth and composition of susceptible Capsicum annuum and resistant Capsicum frutescens, 2-4 weeks after inoculation. Sandhu and Chauhan (1980) characterized mottle disease of chili C. annuum and stated that it had thermal inactivation point between 50-55°C, dilution and point at 1-500 and 1-1,000 and longevity in vitro of 3 days at room temperature. Chauhan, Srivastava and Kinoshita (1981) described that the pepper plants, inoculated with cucumber mosaic virus, were partially male-sterile to variable extent but if inoculated at prefloral bud initiation stage, they were completely

male sterile. Their anthers exhibited abnormalities in the development of endothecium, tapetum and vascular strands. Pieczarka and Zitter (1981) studied the effect of interaction between two viruses and Rhizoctonia on pepper. It was found that viral infection increased plant's suceptibility to Rhizoctonia. Duggal, Singh and Lakhan Pal (1981a,b) described the infection on C. pendulum by potato virus X. It had a negative effect on growth component. The virus infection modified normal tissue in stem, leaf and petiole and damaged phloem tissue very early. Similarly, the differentiation of mesophyll into palisade and spongy parenchyma was lost in the infected leaf. Only the xylem elements were least effected. Sulaiman and Wee (1981) studied symptomatology of tobacco mosaic virus and chili veinal mottle virus infection on chili cultivars and found single inoculation expressing symptoms typical of the isolate whereas mixed infection resulted in plants showing combined symptoms of both isolates. Moorman and Woodbridge (1983) studied morphogenesis of cucumber mosaic virus-induced crystalline inclusions in pepper, a Capsicum annuum cultivar. He observed two types of crystalline inclusions in the epidermis. These crystals attained maximum size in eleven days and disappeared on twenty fifth day at 27°C and on ninteenth day at 32°C.

3.8.2.2 Control of viral diseases:

Roncedo et al. (1975) described the behaviour of four pepper varieties treated with insecticides and this treatment inhibited PVY infection also. Ramallo et al. (1975) reported that direct spraying of mineral oil on pepper crop inhibited potato virus Y. Zhmurko and Bobyr (1975) described the phytotoxicity of "simazine", "atrazine" and "propazine" (0.001%). These produced chlorosis when applied to pepper plant infected with TMV. Dubey and Joshi (1976) found that pyramidine analogues and 2-4-D inhibited the cucumber mosaic virus (CMV) on chilis. Deol and Rataul (1978) studied the role of barrier-crops like sunflower, sesame and pearl-millet in reducing the incidence of cucumber mosaic virus in chili. Prakash and Joshi (1978) found that parachlorophenol (1000 ppm) inhibited CMV infection in chilis.

3.8.2.3 Control of insect vectors of viruses :

3.8.2.4 Chemical control :

Generally virus is transmitted in peppers through different insect species included under 'aphids'. The use of different insecticides can control the spread of viral diseases. Singh, Sastry and Sastry (1979) have evaluated the efficacy of different insecticides and oils in controlling leaf curl virus disease of chili (Capsicum annuum). Its

vector the white fly, Benisia tabaci can be controlled by using "carbofuran" or "disulfoton" at 1.5 kg/ha and four sprays of power oil (1%) at ten days intervals, reduced the incidence of leaf curl disease greatly and increased the yield of chilis two fold. Singh and Rawat (1980) described the damage caused to C. frutescens by the insect Pericallia ricini and found that after the onset of monsoon, the use of "endosulphan 35 Ec" at 0.7% was most effective against the insect larvae. Datar (1980) described the chemical control of chili leaf curl complex by using insecticide, "nuvacron" (0.03%), which was found to be superior to "phosphamidon" (dimecron 0.03%) and to "endrin" (0.03%). Four sprays, starting after two weeks of transplantation and at ten days interval, were very useful. Agnihotri et al. (1983) studied the residues of synthetic prethroid insecticide on Capsicum frutescens (chili) and other plants,

Agrios et al (1985) while studying the effect of cucumber mosaic virus. inoculation, on the growth and yield of Capsicum annuum plants found that the early inoculations more drastically effected the plant size, leaf size, fruit size, and yield as compared to the late inoculations. Atiri et al., (1985) studied the effect of the infection of pepper veinal mottle virus

on the yield in pepper plants and noted that many cultivars of chili were susceptible to this infection resulting in to developments of severe symptoms and yield reduction. There were some cultivated varieties found to be resistant to PVMV. Apablaza et al., (1986) reported that Y strain of Potato Virus Y had a mild effect on Capsicum annuum, variety 'grossum' in the field conditions. Reduction in yield was insignificant in the case of V-R-2 'lamugo' and 'California Wonder'. The variable number of fruits per plant was also not affected. These strains were thought to be resistant.

3.8.3 Fungal diseases, resistance against them and their Control:

Roy (1974) described the following diseases of peppers : 'stem-rot' and 'wilt' caused by Sclerotinia sclerotiorum, anthracnose and die-back diseases caused by Glomerella cingulata and dry fruit-rot caused by Bothryodiploida theobromae. Baltovski (1974) studied the causal agents rapidly degrading pepper C. annuum and found these to be, Fusarium oxysporum, F. vasinfectum, Phytophthora capsici, P. equiseti and Rhizoctonia solani. Dhawale and Kodmelwar (1978) found that chili seeds were infected by microflora e.g. , Aspergillus niger, Chaetomium sp., Colletotrichum capsici, Fusarium sp., Alternaria sp., Rhizoctonia bataticola, Curvularia sp. etc. Uma (1981) described post-harvest diseases of red-pepper caused by Verticillium psalliotae, Fusarium moniliforme and Alternaria species.

Bruin and Edgington (1982) stated that UV radiation produces in many pepper varieties resistance to fungal infection. Mali, Joi and Shinde (1983) listed the fungi associated with chili seeds. These are Alternaria, Aspergillus, Cladosporium, Colletotrichum, Curvularia, Drechslera, Macrophomina and Rhizopus.

Saini and Sharma (1978) studied the inheritance of resistance to fruit-rot in bell-pepper, C. annuum and found that resistance gene can be transferred from one variety to another.

Some varieties of pepper have been found to be resistant to Phytophthora capsici. Kimble and Grogan (1960) reported induction of resistance in bell pepper against fruit-rot caused by P. capsici by hybridizing chinese giant, C. annuum with a globe-fruited type C. frutescens. Clerjeau and Nourrisseau (1976) stated that some pepper varieties have got variable resistance to the infection of Phytophthora capsici. Same kind of resistance in some cultivars was also reported by Molot, Clerjeau, Nourrisseau and Ricci (1976). Kanlong, Somchai and Hendrix (1977) proved that some Phytophthora varieties kill the pepper plant but others only inhibit the plant growth. Jones, Unwin and Ward (1975b) indicated that fungal infection like Phytophthora infestans induced the accumulation of capsidiol in the fruit

tissues of pepper which counteracts the effect of fungal mycelium. Aleksic et al. (1978) studied the control of Phytophthora capsici parasitic on pepper and found that ridomil carbamate and ethyl phosphate controlled the fungus and had no toxic effects on paprika at 0.15 gm/plant. Muchovej et al. (1980) proved that in the presence of $CaCO_3$ and $Ca(OH)_2$ seedling blight of peppers is caused by Phytophthora capsici. Mickovska (1981) proved that, at higher temperature, the plant is very much infected by P capsici. Jones Graham and Ward (1975a,b) have described ultrastructural changes in pepper cell caused by the pathogens Phytophthora infastans, P. capsici and Monilinia fructicola. Molot et al.(1981) described the relationship between capsidiol concentration, spread of fungal invasion and level of induced resistance in cultivars of peppers susceptible or resistant to Phytophthora capsici. Papavizas and Bowers (1981) studied the effectivity of "Captafol" and "Metalaxyl" against Phytophthora capsici on C. annuum and found that "Captafol"was more effective in controlling the pathogen and inhibiting release or germination of spores. Susuri et al. (1979) studied the chemical control of Phytophthora capsici and found that "Defolatan" was more effective than "Orthodifolatan" ,"Captafol" and "Folpet". Pochard and Anne-Marie Daubeze (1980) found that resistance of pepper to Phytophthora capsici is polygenic.

Stephens et al. (1981) devised a method for evaluating post emergence damping-off of pepper plants. Kunoh, Takashima and Ishizaki (1981) recorded the presence of osmiophilic granules associated with the haustoria of powdery-mildew fungus in green peppers. Reuveni, Perl and Rotem (1976) described that shedding of the pepper leaves infected by powdery-mildew and it was inhibited by application of auxins. Blazquez (1976) described a powdery-mildew of chili caused by Oidiopsis sp. Cha, Jaesoon, Unkyeki, Backhocho and Chungkim (1980) reported a new powdery -mildew of Capsicum caused by Oidiopsis taurica. Gohokar and Peshney (1981) studied the chemical control of powdery mildew of chili and found that "Sulphur Sultaf" and "Dinocap" were superior to others in inhibiting fungal-spore germination.

Grewal and Grover (1973) studied the reaction of red pepper, C. frutescens varieties, to the attack of Colletotrichum piperatum. Grewal, Rajendra and Grover (1974) studied the C. frutescens plants infected with Colletotrichum piperatum and found that aminobutyric acid, asparagine and tyrosine were completely degraded after five days of infection, while Beta-alanine, glutamine, glutamic acid glycine and threonine showed some increase. All sugars except xylol were degraded.

Saadon and Meon (1980) described that anthracnose disease of chili had a variable varietal susceptibility to Colletotrichum capsici. Adikaram, Brown and Swinburne (1983) described the infection of Capsicum fruits caused by Glomerella cingulata and Colletotrichum capsici.

Sabel Nikova and Brun (1975) reported the peppers infected with fungus, Verticillium dahliae showed decrease in the content of IAA and tryptophan. Gennari, Gentile and Matta (1979) proved that healthy pepper plants had antifungal substances in their leaves and stems. But the quantity of this substance does not increase after infection with virulent or avirulent or both strains of Verticillium dahliae. Arsenijevic and Sevar (1981) proved that Verticillium dahliae produced wilt in Capsicum also.

Shawkat, Michail, Tarabeih and Alzarari (1978) found that high fruit loss is caused in chilis due to infection by Alternaria sp. Mc Donald and Dewilot (1981) stated that the loss of the packed bell-pepper fruits was caused by seven different fungi causing soft-rot but most of the damage was done by bacterial soft-rot and Alternaria-rot. Halfon and Rylski (1983) described the internal mould of sweet pepper fruit C. annuum caused by Alternaria alternata. Dougherty (1979) has described that bud-rot of pepper is caused by Choanephora cucurbitarum. Neah, Bahadur and Wadudmian (1981) described the pathogenicity of Choanephora cucurbitarum on chili and possibility of its

chemical control by using five fungicides viz. copper oxychloride, dithane M-45, plantvax, vitavax-200 and brassicol. Field resistance to "Cercospora" leaf spot was reported which is controlled by three or more genes (Hare, 1957a; Mississippi, 1957) . Sharma and Sohi (1981) described that chemical control of Cercospora leaf spot of chili using five fungicides viz., bavistin (0.1%), blitox (0.5%), captan (0.2%), difolatan (0.3%) and dithane Z-78 (0.2%). It was found that bavistin was most effective.

Schneider, Roswitha and Crueger (1976) described a new leaf spot disease of chili caused by Stemphylium botryosum . It was also reported by Rochard, Clerjeau and Pitrat (1976). Valdez and Opina (1980) proved that the fungus, Stemphylium lycopersici, can cause grey leaf spot in pepper also. Homma et al.(1980) studied powdery mildew of peppers,caused by Levillula taurica. Perisic and Markovic (1976) described that pepper anthracnosis is caused by Gloesporium piperatum. Thirumalachar, Neergaard and Fakir (1977),proved that seeds of Chili bore the infective spores of Macrophomina phaseolina. Siddiqui, Singh and Gaur (1977) described the prevalence of anthracnose fungus on the seeds of the chili crop and found that they are controlled by sprays of 0.2% 'Thiram' and three sprays of 0.25% 'Difolatan'. Cardoso et al. (1979) has described that Pythium splendens caused the root-rot and damping-off in black pepper seedlings.

Almeida, Robbs, Akiba and Kimura (1980) have described that Rhizoctonia solani also causes disease in pepper. Dood,

Krikum and Haas (1983) Wave indicated the effectiveness of indigenous population of vasicular and arbuscular mycorrhizal fungi on phosphorus intake in pepper plants.

Barksdale, Papavizas and Johnston(1984) described the resistance of pepper to foliar blight and crown rot.

Reddy, Srihari and Rao (1981) studied the cytogenetic effect of insecticides like 'BHC and Nuvacron' on chromosomal mechanism in relation to yield component in chili. They found that yield was not effected by BHC but increased in 0.04% of Nuvacron and decreased in0.12% applications.

Same results were recorded by Baker and Brooks (1976) on infecting chili plants with Monilinia fructicola.

Aleksic et al.(1976) have proposed the measures for controlling the infection of Phytophthora in chili plants like disinfection of seeds with fungicides, of soil with "captafol" or "difolatan" soaking of roots or of other plants parts in 1% suspension of fungicides and spraying of plants immediately after transplantation.

3.8.4 Insect pests of chili and their control :

Very little work has been done on insect pests of Capsicum. Merny and Cadet (1978) studied the penetration

of juveniles and development of adult Heterodera oryzae on pepper plants. Ciampolini and Zangheri (1978) found the "Acephate" insecticide most effective against Spodoptera litteralis, an insect pest of chili. Rao and Reddy (1980) also gave evaluation of some insecticides for controlling the chili pod borer Spodoptera litura and noted that "Acephate","Monocrotophos" and "Quinalphos" were best for lowering this infection on C. annuum . 0.1% "Monocrotophos" reduced the incidence of the disease from 32.98% to 10.69%. Burbutis and Koepke (1981) studied the control of European corn-borer, Ostrinia nubilalis on peppers using Trichogramma nubilale. Chandler (1984) studied the Lirimyza sativae on bell-pepper. Sometimes mere crowding of insects or their nymphs on the branches results into damage to the plants. Hodjat and Bishop (1978) studied the adverse effect of crowding of aphid bymphs (Myzus persicae) on the pepper plant.

Polian Bouin et al(1984) studied the phytotoxic power of 'capsidiol' and specific resistance inductors on pepper. (Capsicum annuum) plant. Gohokar et al.(1985) studied the effect of 12 fungicides on the chili plant infected by Leveillula taurica and found that Marathane was the best for controlling the disease . Molot et al.(1985), described the role of ethylene in the synthesis of capsidiol and the

susceptibility to Phytophthora capsici on pepper treated with elicitor. It was found to increased the resistance in "Yolowonder" but decreased it in Phyo.636.

3.8.5 Nematode Parasites :

During the last ten years much work has been done on plant parasitic nematodes infecting chilis /peppers.

3.8.5.1 General :

Muthu Krishnan, Rajendran and Sekaran (1975) reported pathogenecity of Heliocotylenchus dihystera to C. annuum. Khan, Saxena, Siddiqui and Upadhyay (1975) reported that Helicotylenchus indicus and Meloidogyne incognita also parasitise the chili on which their population increases. Ogbuji (1976) found that chilis are, more or less, susceptible to the inoculation of peanut root-knot nematode, Meloidogyne arenaria. Trivedi and Tiagi (1980) studied histochemically the root-galls of C. annuum caused by Meloidogyne incognita. Ogbuji (1980) studied differential host responses to Meloidogyne sp. Koenning and Mc Clure (1981) studied interaction of two poty-viruses TEV and PeMV and Meloidogyne incognita in chili pepper. Ogbuji (1981) studied variation in the infectivity among population of Meloidogyne javanica on pepper (C.frutescens) cultivars. Alhazmi and Sasser (1982) studied biology of Meloidogyne palatani and stated that it forms galls only slightly in Capsicum frutescens. Bafokuzara (1983) studied influence of

six vegetable-cultivars including peppers on reproduction of Meloidogyne javanica. Townshend, Potter and Davidson (1984) studied some monocot and dicot hosts of Meloidogyne microtyla and he found that chili is one of them. Haseeb, Khan and Saxena (1981) have studied relationship of inoculum density of Rotylenchus reniformis with the growth of chili. Charchar and Huang (1981) studied the host range of Platylenchus brachyurus on bell-pepper C. annuum. Acharya and Das (1983) studied the host-range and pathogenecity of Macroposthonia ornata and found that it parasitises chilis also.

3.8.5.2 Control of nematode parasites :

Frischkorn, Frischkorn and Carrazzoni (1978) showed that the extract of the leaves and fruits of C. annuum shows remarkable cercaricidal effect on Schistosoma mansoni. Siva Kumar et al. (1979) showed the interaction of chili plant with certain systemic nematicides in the population decline of Rotylenchus reniformis. Jaworski et al. (1980) studied the treatment of C. annuum and other plants with fungicides like methylbromide-chloropicrin, [illegible] gas mixture, and other nematicides. This treatment increased the fresh weight of the plants

and side by side reduced the population of Pythium and Fusarium also. Alonso-Allende et al.(1980) studied the persistence of organochlorine pesticides in the soil cultivated with C. annuum. Alam, Khan and Saxena (1981) studied effeciency of nematicides for field-control of nematodes infesting certain vegetable crops like chili. The result of the treatment with nematicides was tremendous increase in the yield. Alam et al. (1980) studied the effect of different cropping sequences on the population of plant parasitic nematodes.

CHAPTER-4

4.1 Materials

The following varieties and species of pepper will be used for experimental work in order to improve yield and other attributes.

4.1.1 Varieties of *Capsicum annuum*

a. Elephant Trunk (ET)
b. California Wonder (CW)
c. Jwala (J)
d. Suryamukhi Black (SB)
e. Suryamukhi Green (SG)
f. New Red Hot (NRH)
g. NP-46A (NP46A)

4.1.2 Other species of *Capsicum*

a. *Capsicum frutescens*
b. *Capsicum pendulum*

4.1.3 Hybrids and Mutants

Interspecific and intervarietal, hybrids F_1, F_2 and F_3 generations, mutants of M_1, M_2, M_3 generations, obtained through mutagenesis, and back cross progeny of BC_1, BC_2, BC_3 generations.

4.2 Treatment of seeds with mutagens

Physical and chemical mutagens and their combinations will be used for inducing mutations.

4.2.1 Chemical mutagenesis

Hundred seeds of each variety will be taken in five replicates of each. These will be treated with 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0% of EMS for 24 hours after being presoaked in DW for 24 hours at room temperature. The treated seeds will be washed throughly in DW to remove any toxic substance used or secreted during treatments. One lot of 100 seeds is to be soaked in DDW for being used as control. Similarly, treatments were given with DES, and Caffeine.

4.2.2 Physical mutagenesis

Four sets of 100 seeds each will be kept in petridishes and soaked in DW for 24 hours. After soaking, three sets of these seeds were exposed to the gamma-rays

so as to receive 1,2 and 5 Kr of irradiation respectively. Fourth set will be kept as control.

4.2.3 Combination of physical and chemical mutagens

Two sets of each variety, with 100 seeds each, will be given irradiation doses of 5 and 10 Kr gamma rays respectively. These will then be soaked in DW for 24hrs and then they will be treated with EMS for 24hrsand after washing, seeds will be sown in sterilised pots.

4.3. Interspecific and intervarietal hybridization

Crosses will be made between different Capsicum annuum varieties and between Capsicum frutescens and different varieties of Capsicum annuum. Emasculation will be done for crossing. Young flower buds, going to open next day, will be selected for emasculation. The flowers will have to be opened with the help of fine forceps and anthers have to be removed one by one without causing injury to the pistil. After emasculation, these buds have to be rebagged to stop unwanted pollination. The buds going to be used as male parents would also be protected in the same manner. Emasculation will be done in the

afternoon and the pollination in the next morning. Pollination will be done with the help of a fine brush which will be used to transfer pollen from freshly dehisced anthers to the stigma of the carpel of the flowers going to be used as female parents. After pollination, the flower buds will be rebagged and laballed. Pollen application will be repeated next morning to ensure fertilization. Butter-paper bags will have to be pin holed at some places to allow air passage. These bags are removed only after fruit set. For selfing, the entire inflorescence is to be bagged before blooming. The seeds of every hybrid fruit will be collected and stored separately. These will be sown next year for obtaining the plants of F_1 generation. The flowers of the plants of F_1 generation will also be similarly bagged and allowed to be self-crossed. Now the seeds of F_2 generation will also be collected and stored separately for being sown next season in order to raise the plants of F_2 generation.

4.4 Colchiploidy

Induction of polyploidy will also be done using 0.1% and 0.2% colchicine solution in 5% squeous solution of dimethyl sulphoxide (DMSO). For colchiploidy, the following three methods will be adopted:

4.4.1 Seeds treatments

50 seeds each in three replicates after being soaked in the two different concentrations of colchicin (0.1% and 0.2%) for the required period (20,24 and 48 hours) will be washed with distilled water before being sown in earthen pots. Percentage of germination and abnormalities will be noted during the germination of seeds and different stages of seedling growth.

4.4.2 Germinated seed treatments

50 seeds are soaked in DDW in 4 replicates. These germinated seeds are kept moist with the colchicine solution of 0.1 and 0.2% for 48 and 24 hours respectively. Than the germinated seeds are washed thoroughly with DDW and sown in the pots, to be transplanted later when they attain a size of 4" to 6".

4.4.3 Seedling-root treatments

50 seeds each in four replicates, are soaked in DDW for 24 hours then these are transplanted and kept in sand for a few days. Now the seedling are taken out from the sand together with some sand so that root-hairs are not broken. These are put in water to remove sand particles and then their roots are kept moist by keeping

them in between cotton pieces kept wet with 0.1% and 0.2% colchicine solution for 24 and 48 hours. Afterwards roots are thoroughly washed with DDW and the seedling are transplanted in the pots singly.

4.4.4 Growing tip treatments

50 seeds each in four replicates are soaked in DDW for 24 hours then they are sown in pots. When the seedlings attain a size of 2-3" then these are transplanted separately in small pots. Fifteen healthy seedling are selected for each of the four treatments. Their tips are now kept moist with the help of non-absorbent cotton piece kept wet with 0.1% and 0.2% colchicine solution for 24 and 48 hours. Now their tips are washed and seedlings are allowed to grow.

These seedlings and plants are to be observed for their morphological features indicating induction of colchiploidy. They are kept separately and their buds are studied for confirmation of their polyploid nature.

4.5 Cytological studies

Cytological observations will be restricted to the meiosis (microsporogenesis only). The buds of suitable sizes from the mutants, hybrids, colchiploids and parents / control of each generation are fixed in Carnoy's fluid (Abs. Al. 6 : Chloroform 3: Acetic acid glacial 1)

for about half an hour. Then these buds are transferred to a mixture of 3 parts of absolute alcohol and 1 part of propionic acid saturated with ferric acetate for a period of 24 hours, at room temperature. The material is to be now thoroughly washed with 70% alcohol and stored in it.

4.5.1 Study of meiosis : Meiosis will be studied from propiono-carmine squashes of pollen mother cell cell (see Swaminathan et al., 1954). Preliminary observation will be made from temporary slides which would be later made permanent using Butyl alcohol schedule (Bahaduri and Gosh, 1954).

4.5.2 Study of Pollen size and fertility

Pollen size and fertility will be studied for all generations including parents, control, M_1, M_2, M_3, F_1, F_2, F_3, C_1, C_2, C_3 and their segregates, from fresh pollen samples. One or two anthers will be squashed in 1% solution of acetocarmine or safranine solution and then covered with coverglass. Stained, full grains with smooth outline will be taken as fertile while unstained, empty or irregular- shaped grains will be taken as sterile.

Diameter of pollen grains will be measured from the fresh pollen of different plants after mounting them in methyl-green glycerine-jelly.

4.6 Incidence of diseases

The occurrence of diseases on the plants will be noted on the basis of apparent systoms.

4.7 Characters to be studied

For the determination of various qualitative and quantitative characters to be used for numerical analysis, the following characters will be studied as given by Pickersgill, Heiser and Mc Neill (1979).

1. Leaf area (cm^2)
2. Leaf pubescence (Square root of no. of hairs per cm^2)
3. Leaf texture (Smooth, rugose, very rugose)
4. Leaf colour (green, purple)
5. Peduncle number per node
6. Peduncle length (mm)
7. Peduncle width(mm)
8. Ratio of peduncle length and peduncle width
9. Calyx teeth (absent, present, slight)
10. Calyx constriction (absent, present)
11. Corolla colour (greenish, greenish white, white)
12. Corolla anthocyanin (absent, present)

13. Corolla spot (absent, present)

14. Other corolla markings (yellow-mark present, yellow mark absent)

15. Corolla length (mm)

16. Corolla tube length (mm)

17. Depth of corolla tubing (corolla length corolla tube length/ corolla length)

18. Anther colour (yellow, purple)

19. Filament constriction (absent, present)

20. Stamen length (mm)

21. Pistil length (mm)

22. Style exertion (pistle length-stamen length)

23. Filament anthocyanin (absent, present)

24. Style-anthocyanin (absent, present)

25. Immature fruit anthocyanin (absent, present)

26. Immature fruit colour (cream, pale green, green, dark green)

27. Red pigment in mature fruits (absent, present)

28. Chlorophyll retention in mature fruit(retained not retained)

29. Inhibition of pigment synthesis in mature fruits (uninhibited, partially inhibited, strongly inhibited)

30. Fruit position(erect, pendent)

31. Fruit pungency (pungent, non-pungent)

32. Fruit disperal(deciduous, non-deciduous).

33. Fruit length (cm)

34. Fruit width or diameter (cm)

35. Fruit size (fruit length x fruit width)

36. Fruit shape (fruit width/fruit length)
37. Inner wall of fruit (rough, smooth)
38. No. of seeds per fruit.
39. Seed width (mm)
40. Seed weight per plant
41. Fruit weight per plant

4.8 Calculation of mean, standard error and coefficient of variability (cv)

Mean and standard error of the quantitative characters of the individuals of every generation or treatment will be calculated as follows with usual meaning of symbols :

$$\text{Mean } \bar{x} = \frac{\Sigma x}{N}$$

and standard error $\sigma_{\bar{x}} = \sqrt{\frac{\Sigma(x)^2 - [\Sigma(x)]^2/N}{N-1}}$

$$\text{or} = \sqrt{\frac{\Sigma[(x-\bar{x})]^2}{(N-1)}}$$

In case of paired readings of the individuals of the two generations or of two treatments, the mean and the standard error of their differences will be calculated as follows :

The mean of difference, $\bar{d} = \frac{\Sigma d}{N}$ where $d = x - x'$.

The standard error of the difference of the two treatments

$$\sigma_d = \sqrt{\frac{\Sigma(d^2) - [\Sigma d]^2 / N}{N-1}}$$

The standard error of mean differences $\sigma_{\bar{d}} = \frac{\sigma_d}{\sqrt{N}}$

For unpaired samples, the means of the sample $\bar{x}_1$ and $\bar{x}_2$ and the standard error of the sample sizes N_1 and N_2, (σx) will be calculated as follows :

$$\bar{x}_1 = \frac{\Sigma x_1}{N_1} \quad , \quad \bar{x}_2 = \frac{\Sigma x_2}{N_2}$$

and standard error,

$$\sigma_{\bar{x}} = \sqrt{\frac{1}{(N_1-1)+(N_2-1)} \left[\Sigma x_1^2 - (\Sigma x_1)\bar{x}_1\right] \left[\Sigma x_2^2 - (\Sigma x_2)\bar{x}_2\right]}$$

4.9 Estimation of the heterosis

Heterosis in case of each hybrid will be estimated as follows :

Heterosis over mean of the parents (MP) $= F_1 - MP \times 100/MP$

Heterosis over the superior parents $= F_1 - SP \times 100/SP$

4.10 Calculation of the coefficient of variability (cv)

The coefficient of variability, in terms of percentages, is calculated in the following manner.

$$C.V. = \frac{\text{Standard error of differences}}{\text{Mean value of the differences}} \times 100$$

4.11. Calculation of the value of 't' and its significance

Composition of the two populations of the two generations or those obtained by two treatments, will be done by t- tests under null hypothesis Ho= The test statistics is : /

For paired populations : $t = \dfrac{\bar{d}}{\sqrt{\dfrac{d}{N}}}$.

For unpaired populations : $t \quad \dfrac{x_1 - x_2}{x} \quad \dfrac{N_1 N_2}{N_1 + N_2}$

Value of 't' (at 5% or 1%, confidence levels) for a corresponding degree of freedom is taken from the table. If the calculated value of 't' is larger than the table-value then the differences between the two treatments (two samples of the two populations) are taken as significant.

CHAPTER-5

OBSERVATION

A few preliminary experiments were performed to determine the effect of chemical mutagens such as EMS, DES and caffeine on the percentage of seed germination, rate of the growth of the seedlings and the induction of certain abnormalities in the cotyledonary leaves in the treated population of M_1 generation.

5.1 Effect of mutagens on seed germination

Seeds were treated with 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0% EMS, DES and caffeine. These were sown in pots containing well manured soil. Germination in controls started on the 6th day but in the case of treatments with mutagens it was delayed by 1,2 or 3 days, depending upon the concentration of the mutagen used.

Percentages of seed germination, in controls as well as in the materials treated with EMS, DES and caffeine, have been given in Table 2 and 3 while LD_{50} doses in the graphs A-F.

5.2 Effect of Seed treatment with mutagens on the length of the seedlings

Effect of mutagens on the length of the seedlings of 'JWALA' and 'G_4' was studied.

The seeds of 'JWALA' and 'G_4' varieties were treated with 0.5, 1.0, 1.5,2.0, 2.5 and 3.0% EMS, DES and caffeine. The lengths of the seedlings were noted on the 25th day of sowing. The data on the effect of mutagens on JWALA are given in Table 4 and on 'G_4' in Table 5.

TABLE -2 : Seed germination control and treated materials in the variety, 'JWALA ' of Capsicum annuum L.

Treatment	Initiation of Germination (days after sowing)	50% Germination (days after sowing)	Maximum Germination (days after sowing)	Maximum Germination (%)
Control	6(21)	10(39)	15	78
EMS-0.5%	6(11)	11(33)	15	66
EMS-1.0%	7(19)	11(28)	15	55
EMS-1.5%	7(18)	12(25)	14	49
EMS-2.0%	8(14)	12(24)	15	45
EMS-2.5%	8(10)	12(16)	12	32
EMS-3.0%	9(8)	13(12)	14	22
DES-0.5%	6(11)	11(30)	14	60
DES-1.0%	7(10)	11(27)	15	52
DES-1.5%	8(13)	12(22)	15	45
DES-2.0%	8(10)	10(19)	12	40
DES-2.5%	9(8)	10(15)	13	30
DES-3.0%	9(6)	12(11)	14	20
Caff.0.5%	6(15)	10(36)	15	72
Caff.1.0%	6(16)	11(31)	14	62
Caff.1.5%	6(12)	12(26)	15	52
Caff.2.0%	6(10)	12(17)	15	42
Caff.2.5%	7(11)	10(15)	14	32
Caff.3.0%	8(9)	12(15)	15	30

100 Seeds were sown for each treatment.
Figures in perenthesis show the number of seeds germinated.

TABLE -3: Seed germination in control and treated materials in the variety, G_4, of Capsicum annuum L.

Treatment	Initiation of Germination (day after sowing)	50% Germination (days after sowing)	Maximum Germination (days after sowing)	Maximum Germination (%)
Control	6(4)	10(40)	15	80
EMS-0.5%	6(9)	11(34)	15	66
EMS-1.0%	6(9)	11(28)	14	55
EMS-1.5%	7(9)	12(26)	14	50
EMS-2.0%	7(7)	10(21)	12	40
EMS-2.5%	8(10)	12(27)	15	52
EMS-3.0%	9(7)	11(12)	13	22
DES-0.5%	6(6)	11(30)	15	60
DES-1.0%	7(6)	10(28)	14	55
DES-1.5%	7(10)	12(23)	15	45
DES-2.0%	8(6)	11(21)	15	40
DES-2.5%	9(4)	10(15)	13	30
DES-3.0%	9(6)	11(13)	13	25
Caff.0.5%	6(12)	10(36)	15	72
Caff.1.0%	6(13)	10(32)	14	62
Caff.1.5%	7(10)	11(26)	15	52
Caff.2.0%	7(9)	10(22)	14	42
Caff.2.5%	8(10)	10(15)	13	30
Caff.3.0%	8(9)	10(14)	12	26

100 Seeds were sown for each treatment.

Figures in parenthesis show the number of seeds germinated.

TABLE -4: Length of seedlings in control and treated materials in the variety, 'JWALA' of *Capsicum annuum*

Treatment	Analysis of length of seedlings (cm) for		
	Range	Mean± S.D.	CV (%)
Control	15.4.-22.6	19.3±2.89	14.97
EMS-0.5%	18.2-28.8	21.0±3.86	18.37
EMS-1.0%	15.6-25.5	20.9±2.99	14.34
EMS-1.5%	14.5-27.7	19.8±4.46	22.56
EMS-2.0%	13.7-25.3	18.2±3.35	18.45
EMS-2.5%	12.2-25.3	18.0±4.08	22.67
EMS-3.0%	04.9-09.2	06.7±1.68	25.16
DES-0.5%	13.8-28.2	22.4±4.03	18.00
DES-1.0%	16.4-25.6	20.8±3.29	15.83
DES-1.5%	08.2-25.9	18.9±7.37	38.99
DES-2.0%	13.6-23.1	18.6±2.95	15.86
DES-2.5%	11.5-28.5	18.3±4.96	27.14
DES-3.0%	10.9-31.1	17.6±6.34	36.05
Caff.-0.5%	08.2-23.8	17.7±4.42	24.98
Caff.-1.0%	10.1-21.9	17.6±4.11	23.38
Caff.-1.5%	09.8-17.3	13.4±2.22	16.57
Caff.-2.0%	08.8-22.2	13.3±4.94	37.18
Caff.-2.5%	06.0-18.0	13.1±5.89	45.00
Caff.-3.0%	04.0-11.5	07.5±1.09	14.48

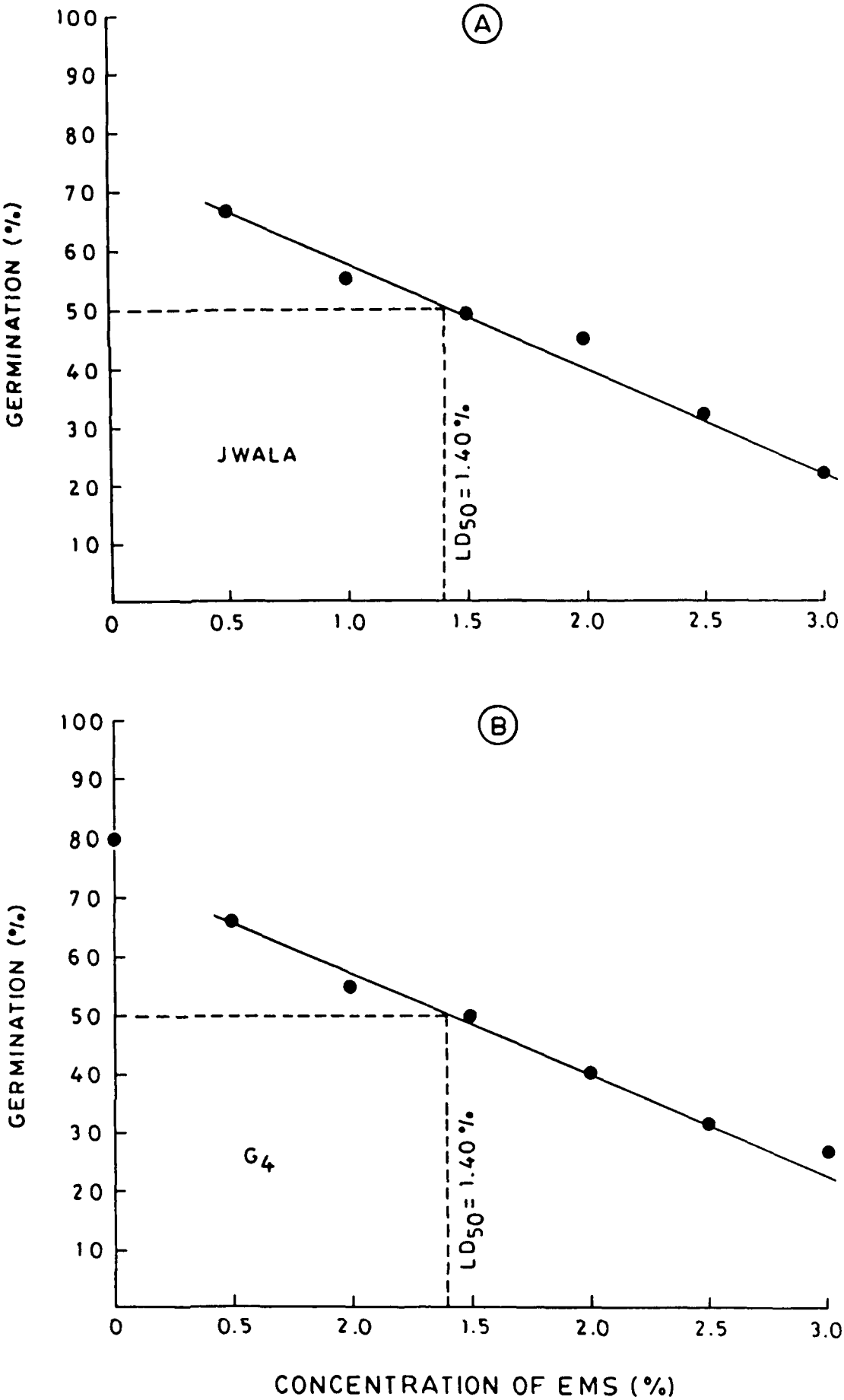
TABLE -5: Length of Seedlings in control and treated materials in the variety, 'G_4' of Capsicum annuum ,

Treatment	Analysis of Length of seedlings (cm) for		
	Range	Mean±S.D	CV(%)
Control	16.4-24.9	19.7±2.54	12.89
EMS-0.5%	10.8-25.2	20.4±4.90	24.03
EMS-1.0%	12.5-24.5	19.9±5.50	27.66
EMS-1.5%	14.7-26.3	19.6±4.22	21.53
EMS-2.0%	12.8-22.2	17.4±3.97	22.82
EMS-2.5%	09.9-21.1	17.3±3.16	18.28
EMS-3.0%	10.1-19.9	15.3±3.46	22.64
DES-0.5%	15.3-25.3	19.6±2.98	15.24
DES-1.0%	10.2-26.8	19.4±6.09	31.41
DES-1.5%	11.4-30.2	19.3±5.30	27.40
DES-2.0%	17.6-22.3	19.1±2.60	13.61
DES-2.5%	03.7-29.2	16.1±7.65	47.52
DES-3.0%	08.5-17.0	14.1±3.94	28.00
Caff.-0.5%	12.6-27.2	19.5±4.60	23.58
Caff.-1.0%	11.9-19.2	14.6±2.36	16.20
Caff.-1.5%	03.6-19.5	10.9±5.27	48.14
Caff.-2.0%	05.2-13.4	10.6±3.06	28.88
Caff.-2.5%	06.7-13.3	09.4±2.50	26.62
Caff.-3.0%	05.8-11.2	08.1±2.23	27.56

EXPLANATION OF FIGURES

Fig.A. LD_{50} dose of EMS for the variety JWALA of *Capsicum annuum* L.

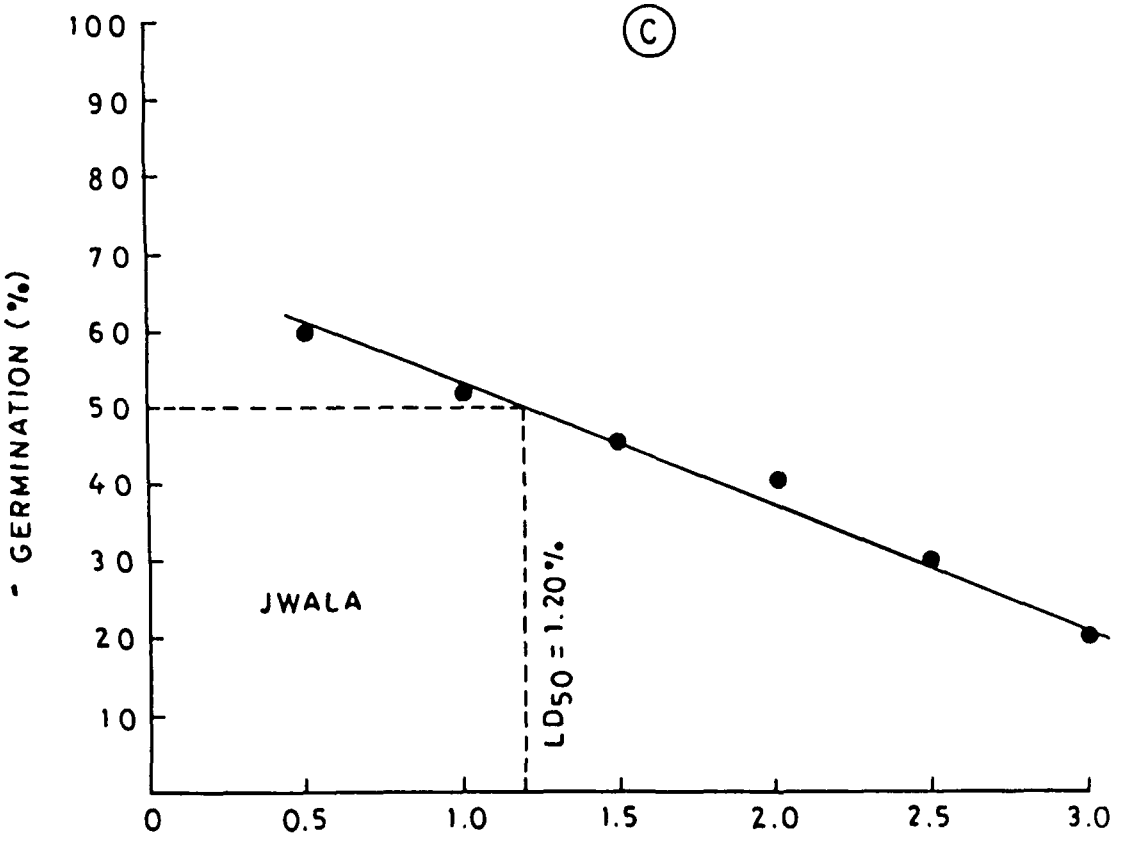
Fig.B. LD_{50} dose of EMS for the variety G_4 of *Capsicum annuum* L.

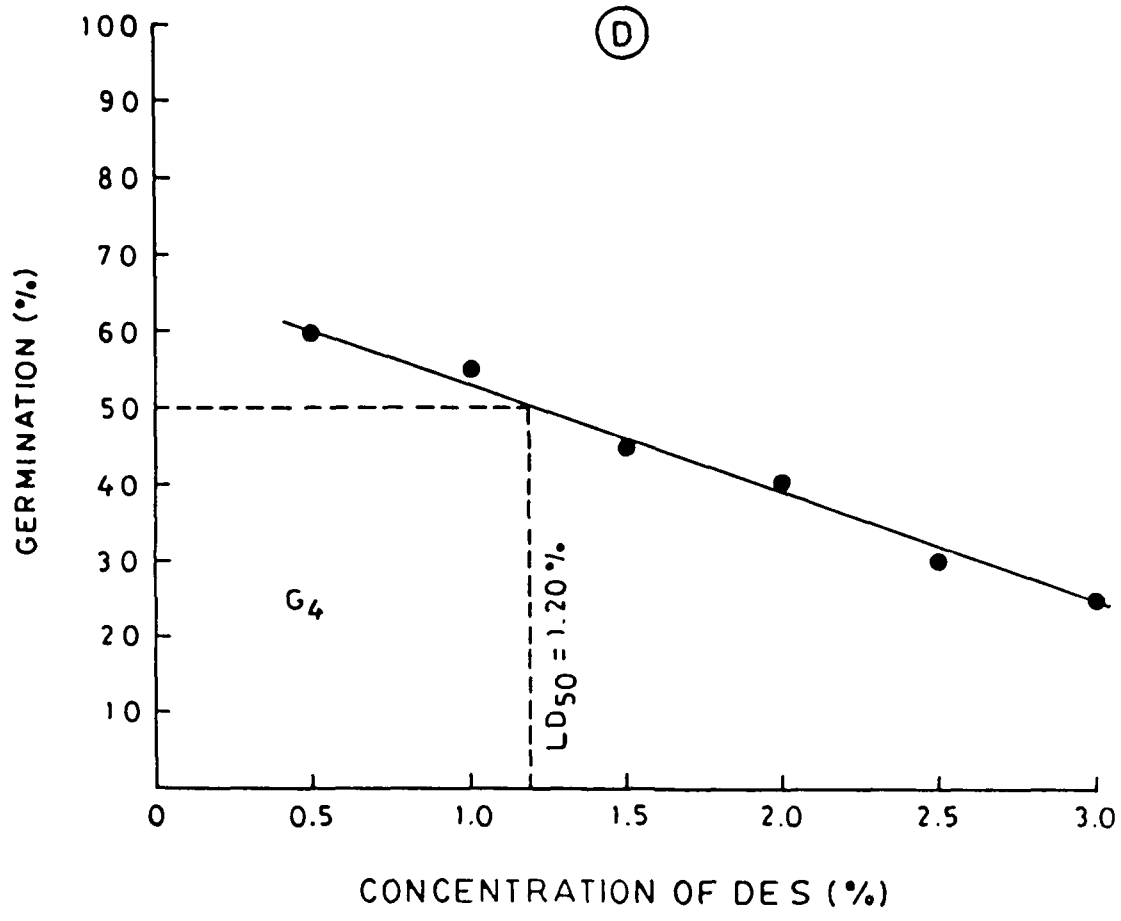

A
100
90
80
70
60
50
40
30
20
10
GERMINATION (%)
JWALA
LD50= 1.40 %
0
0.5
1.0
1.5
2.0
2.5
3.0
B
100
90
80
70
60
50
40
30
20
10
GERMINATION (%)
G4
LD50= 1.40 %
0
0.5
2.0
1.5
2.0
2.5
3.0
CONCENTRATION OF EMS (%)

EXPLANATION OF FIGURES

Fig. C. LD_{50} dose of DES for the variety JWALA of *Capsicum annuum* L.

Fig. D. LD_{50} dose of DES for the variety G_4 of *Capsicum annuum* L.

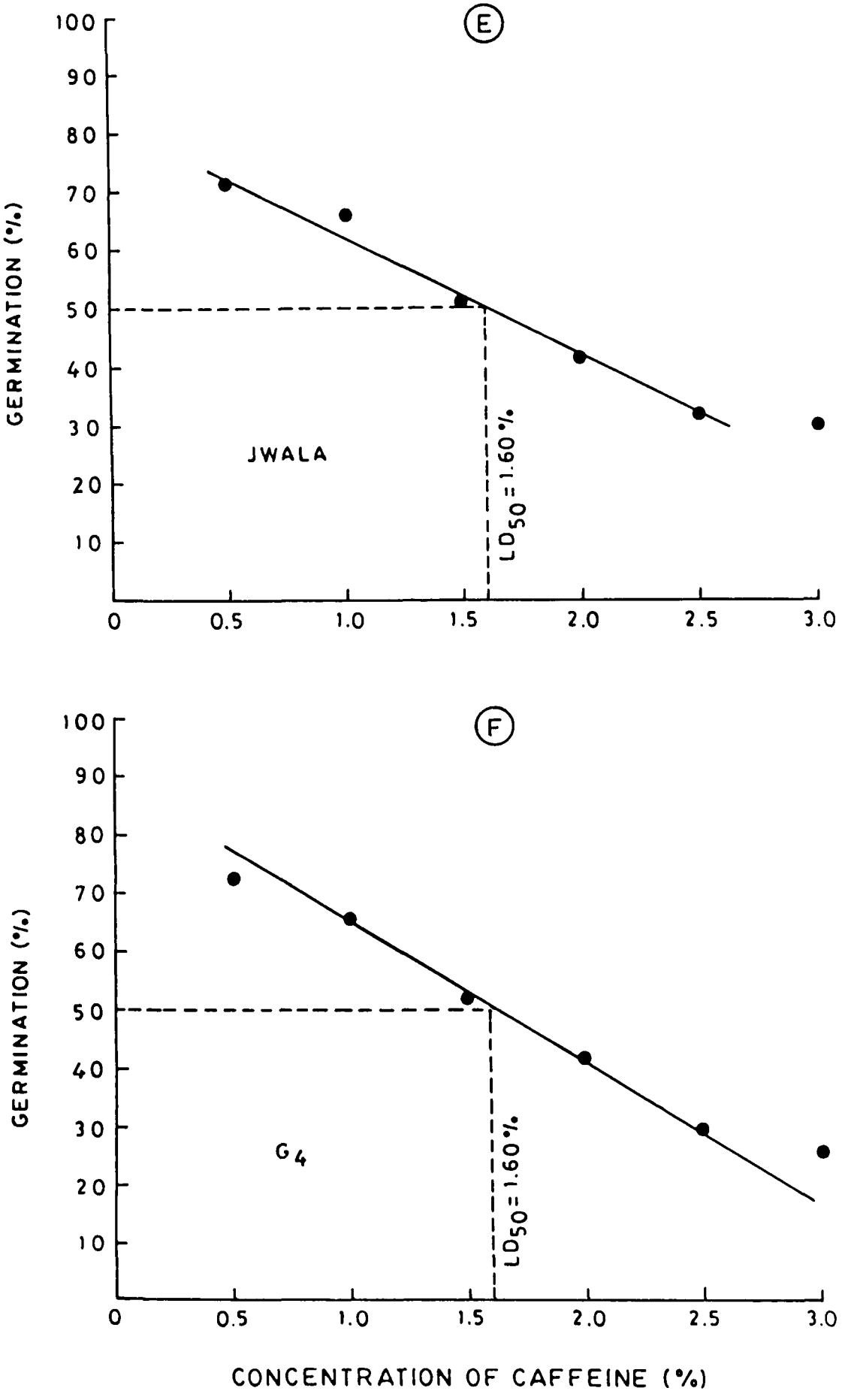

C
100
90
80
70
60
50
40
30
20
10
- GERMINATION (%)
JWALA
LD50 = 1.20%
0
0.5
1.0
1.5
2.0
2.5
3.0


D
100
90
80
70
60
50
40
30
20
10
GERMINATION (%)
G4
LD50 = 1.20%
0
0.5
1.0
1.5
2.0
2.5
3.0
CONCENTRATION OF DES (%)

EXPLANATION OF FIGURES

Fig. E. LD_{50} dose of Caffeine for the variety JWALA of *Capsicum annuum* L.

Fig. F. LD_{50} dose of Caffeine for the variety G_4 of *Capsicum annuum* L.


E
100
90
80
70
60
50
40
30
20
10
GERMINATION (%)
JWALA
LD50=1.60%
0
0.5
1.0
1.5
2.0
2.5
3.0
F
100
90
80
70
60
50
40
30
20
10
GERMINATION (%)
G4
LD50=1.60%
0
0.5
1.0
1.5
2.0
2.5
3.0
CONCENTRATION OF CAFFEINE (%)

CHAPTER-6

DISCUSSION

The observations taken from the seedlings treated with various concentrations of mutagens like EMS, DES and caffeine clearly show the initial stimulating effect of mutagens in some cases but increasingly depressive effect, with the increasing concentration of the mutagens, in all other cases.

In both the varieties, JWALA and 'G_4' increasing dose of mutagen decreases the percentage of seed germination. In JWALA and 'G_4' both 1.5% EMS, 1.2% DES and a little more than 1.5% caffeine resulted into 50% germination (L.D.50). 3.0% concentration of mutagen reduced the percentage of germination to nearly 22-25% in the case of EMS and DES respectively while to 26-30% in the case of caffeine (see graphs A-F). Reduction in germination following mutagenic treatments may be due to the disturbance of the balance which exists between the promotors and inhibitors, probably, in favour of the inhibitory substances in the seeds (Maherchandani 1975).

IN JWALA 0.5 and 1.0% EMS showed an stimulatory effect and seelings were longer while 1.5% EMS was

ineffective but 2.0, 2.5 and 3.0 % EMS showed increasingly depressing effects on the length of the seedlings whereas DES 0.5 and 1.0% also showed stimulatory effect while 1.5,2.0,2.5 and 3.0% DES depressed the lengths of the seedlings in an increasing order. But in the case of caffeine, no stimulatory effect was seen. The concentration of mutagen 0.5-3.0% showed increasingly depressive effect on the length of the seedlings. The effect of 3.0 % caffeine was most drastic and the length of the shoot was reduced to nearly half of that of control.

In the case of 'G_4', 0.5% EMS showed stimulatory effect on the length of seedlings while 1.0 and 1.5% EMS were ineffective. Concentrations of 2.0,2.5 and 3.0% EMS showed increasingly depressive effect on the length of the shoot. DES showed no stimulatory effect at 0.5% level, 1.0 and 1.5% were not very effective and 2.0% had mild depressing effect while 2.5 and 3.0% DES had very stong depressing effect on the length of seedlings. Caffeine 0.5% solution showed no effect while 1.0,1.5,2.0,2.5 and 3.0% caffeine solution showed very strong depressive effects on the length of the seedlings. Stimulatory effect of mutagens at lower concentrations may be due to their action as growth promoting substances while at higher concentration they might have acted as inhibitors (Konzak *et al.*, 1961).

CHAPTER-7

FUTURE PLANT OF WORK

Attempts will be made to obtain improved varieties through the induction of mutation, colchiploidy and hybridization. The following experiments will be performed and M_1, M_2, M_3, C_1, C_2, C_3, F_1, F_2 and F_3 generations will be studied thoroughly from morphological , cytological and yield and diseases-resistance points of view for the purpose of developing improved strains.

7.1 Induction of mutation

Physical and chemical mutagens will be used on dry and presoaked seeds. Comparative observations on morphology, yield components and yield of treated and untreated materials will be recorded for detecting nature and extent of mutations. Beneficial mutations will be isolated and tested for stability upto M_3- generation. Both physical and chemical mutagens and their combinations will be used.

2.1.1 Induction of mutation using chemical mutagens

Caffeine, EMS, DES, will be used in six doses of 0.5%, 1.0%, 1.5%.2.0 %, 2.5% and 3.0% concentration in aqueous solutions for 24 hours. Seeds presoaked in

distilled water for 24 hours, will be treated with aqueous solutions of mutagens. These seeds will then be thoroughly washed with DW before being sown in pots / field.

7.1.2 Induction of mutation using physical mutagen

Dry seeds as well as seeds, presoaked for 24 hours in DW, will be irradiated with gamma rays in doses of 10 and 15 Kr, before being sown. 100 seeds will be taken for each treatment as well as for control.

7.1.3 Combined treatments

Different chemical mutagens will be given in combination with gamma rays for effective induction of mutation. 100 seeds will be used for each treatment. These seeds will be soaked in water for 24 hours. Then these soaked seeds will be treated with mutagens like EMS or NMU for 24 hours, in all given concentrations, then these will be thoroughly washed with DW and put in new petridishes with filter papers and then exposed to different doses of irradiation (10 and 15 Kr). Then these will be sown in the pots already sterilised.

7.2 Induction of colchiploidy

The aims of colchiploidy experiments will be two-fold, first to develop improved lines and the second to induce fertility in the sterile allopolyplóids. Polyploids

and amphidiploids will be produced and a comparative study of their morphology and yield components will be made in the treated materials as well as in the control. Colchicine dissolved in 5% aqueous solution of dimethyl sulphoxide (DMSO, after Siddiqui and Majid, 1969) will be used in concentrations of 0.1 and 0.2% and these will be used for 20,24, 48 and 72 hours. Treatment will be given to the dry seeds, germinated seeds, radicle of germinated seeds and growing tips of young seedlings (for 2-8 hours only for the last two materials) in order to develop polyploid stock.

7.2.1 Induction of autopolyploidy :

Production of polyploids (autotetraploids, hexaploids or plant of higher ploidy levels) will be attempted in order to produce better fruits and higher yield.

7.2.2 Induction of amphidiploidy

Allopolyploids are produced as a result of crosses between two distant relatives, varieties, species or genera. These are generally sterile. Their sterility will be overcome by doubling the chromosome number by using colchicine to produce amphidiploids.

7.3 Hybridization programme

Following varieties of C. annuum will be used for intervarietal crosses with a view to pooling together desirable characters from different. parents:

(a) Elephant Trunk (ET)

(b) California Wonder (CW)

(c) Jwala (J)

(d) Suryamukhi Black (SB)

(e) Suryamukhi Green (SG)

(f) New Red Hot (NRH)

(g) NP46

Similarly C. frutescens and C. pendulum will be used for producing interspecific hybrids (F_1). F_2 and F_3 generations will be produced by selfing F_1 and F_2 generations respectively. Morphology, yield and cytogenetics of F_1, F_2 and F_3 generations will be studied.

7.3.1 Interspecific crosses

Reciprocal crosses will be made between different varieties of Capsicum annuum, C. frutescens and C. pendulum.

7.3.2 Intervarietal crosses

All the seven varieties of C. annuum, selected for experimental, work, will be reciprocally crossed with each other to produce intervarietal hybrids.

7.3.3 Production of F_2 and F_3 generation hybrids

Members of F_1 and F_2 generations will be self-crossed to produce F_2 and F_3 generations respectively. These

generations will be studied for desirable gene combinations, producing better and more fruits.

7.3.4 Back crosses

Following back crosses will be performed in order to transfer one or a few desirable qualities from one parent to another :

7.3.4.1 Back-crosses of F_1 hybrids (BC-1 and BC-2 progeny)

F_1 hybrids of intervarietal and interspecific crosses will be back-crossed with their respective parents to produce BC-1 generation and these will be self-crossed to produce BC- 2 generation.

7.3.42 Back-crosses of amphidiploids (BC-1 and BC-2 progeny)

Amphidiploids produced will also be back-crossed with their respective parents or their autotetraploids to produce BC-1 generation and these will be self-crossed to produce BC-2 generation.

7.4 Selection

Intensive selection experiments will be conducted to obtained improved lines. It is proposed to adopt both mass-selection and progeny-selection methods.

7.4.1 Selection from hybrids materials

This material will be comprising of interspecific and intervarietal hybrids and their progenies (F_1 , F_2, F_3,

BC_{-1}, BC_{-2} and BC_{-3} generations) from which suitable selections will be made.

7.4.2 Selection of mutants

Mutants (M_1) with desirable characters will be isolated and will be self-crossed to produce M_2 and M_2 plants will be self-crossed to produce M_3 generation. From this population stable mutants will be selected.

7.4.3 Selection of polyploids

Similarly selection will be made from the polyploid population, produced through colchiploidy. Plants with desirable traits will be isolated (C_1) and will be self-crossed to produced C_2 and C_2 will be self-crossed to produce C_3 generation.

7.5 Cytogenetic studies

Cytogenetic behaviour of the products of the above mentioned experiments will be studied during the meiosis in the microspore mother cells and will be compared with that of control parents.For this purpose, the procedure following Bhaduri and Ghosh (1954) will be adopted. This will include the following :

7.5.1 Cytogenetic study of hybrid material

This material shall include all F_1 hybrids as well as their progeny.

7.5.1.1 Interspecific hybrids

7.5.1.2 Intervarietal hybrids

7.5.1.3 Back-cross progeny of F_1 hybrids

7.5.2 Cytogenetics of mutants

These mutants will be of M_1, M_2 and M_3 generation.

7.5.2.1 Back cross progeny of M series

7.5.3 Cytogenetics of polyploids

The polyploids shall include :

7.5.3.1 Autopolyploids

7.5.3.2 Amphidiploids

7.6 Breeding for disease-resistance

Disease-resistance of improved varieties will be studied in comparison to the control and parents. The ability of germinating seeds to grow away from pathogens present in soil, will be taken as an indicator of disease-resistance. Resistance of plants against the pests will also be noted. Resistance will be studied in the following manner.

7.6.1 Resistance against fungal diseases

7.6.2 Resistance against bacterial diseases

7.6.3 Resistance against viral diseases

7.6.4 Resistance against insect pests

7.7 Floral biology

Floral biology of all varieties of C. annuum and all other available species of Capsicum will be studied including the study of longevity of pollen, receptivity of stigma and patterns of anthesis.

7.8 Testing and establishing the selections

An attempts will be made to start preliminary experiments for testing the selections, made during the course of this work for determining their genetic purity and consistancy. It is intended to attempt to stabilise different desirable characters obtained in selections and then the seeds will be released to the farmers through proper agencies.

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